THE JOURNAL and CERAMIC ABSTRACTS

AMERICAN CERAMIC SOCIETY

JUNE • 1938

MONTHLY PUBLICATION DEVOTED TO THE ARTS AND SCIENCES RELATED TO THE SILICATE INDUSTRIES

TABLE OF CONTENTS

Vol. 21 June, 1938 No. 6

THE JOURNAL

Surface Properties of Fused Salts and Glasses: I, Sessile-Drop Method for Determining Surface Tension and Density of Viscous Liquids at High Temperatures 193
By B. S. Ellefson and N. W. Taylor

Surface Properties of Fused Salts and Glasses: II, Contact Angle and Work of Adhesion on Gold and Platinum in Various Atmospheres 205
By B. S. Ellefson and N. W. Taylor

Comment on Barrett and Taylor's Method for Studying the Flow Characteristics of Glasses and Slags at Elevated Temperatures 213
By J. H. D. Heine

Reply to Discussion 214
By J. A. Taylor and E. P. Barrett

Electrically Fused Magnesia 216
By H. E. White

Use of Talc and Pyrophyllite in Semivitreous Dinnerware Bodies 229
By E. H. Lintz

CERAMIC ABSTRACTS

17—6

Abrasives 207
Art and Archeology 209
Cements 211
Enamel 212
Glass 214
Structural Clay Products 219
Refractories 220
Terra Cotta 223
Whiteware 223
Equipment and Apparatus 224
Kilns, Furnaces, Fuels, and Combustion 227
Geology 229
Chemistry and Physics 232
General 236

Publication Office: 20th & Northampton Sts., Easton, Pa.
Editorial Office: 2525 N. High St., Columbus, Ohio
Entered as second-class matter at the post office at Easton, Pa., under the act of March 3, 1879. Published monthly.
Subscription fifteen dollars ($15.00) a year. Single numbers $1.50
(Foreign and Canadian postage, 50c additional on subscriptions)
(Copyright 1938, American Ceramic Society, Inc.)

THE AMERICAN CERAMIC SOCIETY TRUSTEES AND OFFICERS FOR 1938–1939

President: V. V. Kelsey, 1403 Trenton Trust Bldg., Trenton, N. J.
Vice-President: A. I. Andrews, University of Illinois, Urbana, Ill.
Treasurer: C. Forrest Tefft, The Claycraft Co., Box 866, Columbus, Ohio
Secretary-Editor: R. C. Purdy, 2525 North High St., Columbus, Ohio
Past-President: R. B. Sosman, United States Steel Corp., Research Lab., Kearny, N. J.
Past-President: F. C. Flint, Hazel-Atlas Glass Co., Zanesville, Ohio

TRUSTEES FROM INDUSTRIAL DIVISIONS*

Art: L. E. Barringer, General Electric Co., Schenectady, N. Y. (1940)
Enamel: H. G. Wolfram, Porcelain Enamel & Mfg. Co., Baltimore, Md. (1940)
Glass: D. E. Sharp, Hartford-Empire Co., Hartford, Conn. (1941)
Materials and Equipment: G. H. Brown, Rutgers University, New Brunswick, N. J. (1939)
Refractories: C. E. Bales, Ironton Fire Brick Co., Ironton, Ohio (1940)
Structural Clay Products: J. L. Child, Hancock Brick & Tile Co., Findlay, Ohio (1939)
Terra Cotta: J. L. Carruthers, Ohio State Univ., Columbus, Ohio (1939)
White Wares: E. H. Fritz, Westinghouse Electric & Mfg. Co., Derry, Pa. (1941)

* Date of expiration of term of office in parentheses.

DIVISION OFFICERS

Art
Chairman: A. E. Baggs, Ohio State Univ., Columbus, Ohio
Secretary: C. C. Engle, United Clay Mines Corp., Trenton, N. J.

Enamel
Chairman: G. H. Spencer-Strong, Porcelain Enamel & Mfg. Co., Baltimore, Md.
Secretary: D. G. Bennett, Mellon Institute, Pittsburgh, Pa.

Glass
Chairman: L. C. Roche, Maryland Glass Corp., Baltimore, Md.
Secretary: S. R. Scholes, N. Y. State College of Ceramics, Alfred, N. Y.

Materials and Equipment
Chairman: R. B. Carothers, H. C. Spinks Clay Co., Newport, Ky.
Secretary: B. T. Bonnot, The Bonnot Co., Canton, Ohio

Refractories
Chairman: N. W. Taylor, Pennsylvania State College, State College, Pa.
Secretary: J. B. Austin, Research Lab., U. S. Steel Corp., Kearny, N. J.

Structural Clay Products
Chairman: T. W. Garve, 314 King Ave., Columbus, Ohio
Secretary: H. Z. Schofield, O. S. U. Engineering Experiment Station, Columbus, Ohio

Terra Cotta
Chairman: H. E. Davis, Federal Seaboard Terra Cotta Co., South Amboy, N. J.
Secretary: D. F. Albery, Edward Orton, Jr., Ceramic Foundation, Columbus Ohio.

White Wares
Chairman: F. P. Hall, Onondaga Pottery Co., Syracuse, N. Y.
Secretary: Karl Schwartzwalder, A C Spark Plug Co., Flint, Mich.

OFFICERS OF THE FELLOWS

Dean: Paul E. Cox, Iowa State College, Ames, Iowa
Associate Dean: W. Keith McAfee, Universal Sanitary Manufacturing Co., New Castle, Pa.
Secretary-Treasurer: R. K. Hursh, University of Illinois, Urbana, Ill.

LOCAL SECTIONS

Baltimore-Washington
Chairman: G. H. Spencer-Strong, Porcelain Enamel & Mfg. Co., Baltimore, Md.
Secretary: J. D. Tetrick, Baltimore Enamel & Novelty Co., Baltimore, Md.

Central Ohio
Chairman: H. Z. Schofield, O. S. U. Engineering Experiment Station, Columbus, Ohio
Secretary: R. P. Graham, Battelle Memorial Institute, Columbus, Ohio

Chicago
President: A. L. Vodicka, Aetna Porcelain Enameling Co., Chicago, Ill.
Secretary: Rexford Newcomb, Jr., Industrial Publications, Inc., Chicago, Ill.

Michigan-Northwestern Ohio
Chairman: Karl Schwartzwalder, A C Spark Plug Co., Flint, Mich.
Secretary: R. O. Lane, Macklin Co., Jackson, Mich.

Northern California
Chairman: C. S. Chaffee, Owens-Illinois Pacific Coast Co., San Francisco, Calif.
Secretary: G. A. Page, Stockton Fire Brick Co., Pittsburg, Calif.

Pacific-Northwest
President: F. G. Burrows, Chehalis Brick & Tile Co., Chehalis, Wash.
Secretary: Hewitt Wilson, Univ. of Washington, Seattle, Wash.

Pittsburgh
Chairman: D. G. Bennett, Mellon Institute, Pittsburgh, Pa.
Secretary: C. L. Thompson, Harbison-Walker Refractories Co., Pittsburgh, Pa.

Southern California
Chairman: T. S. Curtis, Huntington Park, Calif.
Secretary: F. A. McCann, 714 Heatherside Rd., Pasadena, Calif.

St. Louis
Chairman: C. M. Dodd, Missouri School of Mines, Rolla, Mo.
Secretary: R. S. Bradley, A. P. Green Fire Brick Co., Mexico, Mo.

COMMITTEE ON PUBLICATIONS

Chairman: J. D. Sullivan, Battelle Memorial Institute, Columbus, Ohio
E. deF. Curtis, Conestoga Pottery, Wayne, Pa.
E. E. Marbaker, Mellon Institute, Pittsburgh, Pa.
W. W. Winship, Thermal Syndicate, New York, N. Y.
R. C. Purdy, 2525 North High St., Columbus, Ohio
Editorial and Advertising Offices:
The American Ceramic Society, 2525 North High Street, Columbus, Ohio

SURFACE PROPERTIES OF FUSED SALTS AND GLASSES: I SESSILE-DROP METHOD FOR DETERMINING SURFACE TENSION AND DENSITY OF VISCOUS LIQUIDS AT HIGH TEMPERATURES*

By Bennett S. Ellefson† and Nelson W. Taylor

Abstract

An apparatus is described which allows measurements to be made of the contact angle and the exact dimensions of a sessile drop of liquid resting on an electrode graphite surface *in vacuo* or in nitrogen atmosphere. Temperatures up to 1100°C have been employed. Under these conditions, surface tension and gravity are the only forces acting on the drop, and the exact shape, surface, and volume may be computed from the tables of Bashforth and Adams. The method may be used with liquids having viscosities up to 600 poises, whereas the bubble-pressure method used by Jaeger is limited to liquids of viscosity less than 70 poises.

On the basis of internal evidence, the surface-tension values obtained by the sessile-drop method are considered correct within 5%. They also agree with data by Jaeger, but are, roughly, twice as great as those of Washburn and Libman, who used a ring method. The probable error in Washburn and Libman's work appears to be in their assumption of zero contact angle.

I. Introduction

The methods which have been used for the measurement of surface tension can be divided into two classes, static and dynamic. The term "dynamic" shall describe any method which involves a dynamic process to indicate the attainment of the end-point in the measurements.

II. Historical Review

(1) Surface Tension of Glasses

The high viscosity of some melts combined with their corrosive nature makes the measurement of the equilibrium value of surface tension at high temperature difficult. These difficulties and means of circumventing them are discussed in detail in previous reports on high-temperature surface-tension measurements; some of these are listed in chronological order as follows:

(1) Static (1868): Sessile-drop method, using an approximation formula in calculations (Quincke).[1]
(2) Dynamic (1911): Drop-weight method (Tillotson).[2]
(3) Dynamic (1917): Maximum bubble-pressure method (Jaeger).[3]
(4) Static (1920): Sessile-drop method, procedure not described;· also sagging-fiber method (Griffith)[4].
(5) Static (1924): Hanging-cylinder method, in reality a static modification of the anchor-ring method (Washburn and Libman).[5]
(6) Static (1936): "Soap-bubble" method, involves difficulty of maintaining bubble (Pietenpol).[6]
(7) Dynamic (1937): Maximum bubble-pressure method (Parmelee and Harman).[7]

(2) Density

Of the seven methods named, Nos. (1) and (4) necessitate a knowledge of the density of the liquid at the high temperature in order to obtain an absolute value of the surface tension; Nos. (3), (5), and (7) utilize a density value only in correction terms. The measurement of densities at high temperatures has been discussed by (*a*) Jaeger,[3] 1917; (*b*) Washburn and Libman,[5] 1924; and (*c*) Parmelee and Harman,[7(a)] and Parmelee and Lyon,[7(b)] 1937; and (*d*) Hänlein, 1932.[7(c)]

* Presented at the Thirty-Ninth Annual Meeting, American Ceramic Society, New York, N. Y., March 23, 1937 (Glass Division). Received August 2, 1937.

† Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, Pennsylvania State College, February, 1937.

[1] G. Quincke, *Ann. Phys. Chemie*, **135**, 621 (1868); **138**, 141 (1869).

[2] E. W. Tillotson, "Surface Tension of Molten Glasses," *Jour. Ind. Eng. Chem.*, **3**, 631–37 (1911); **4**, 651–52 (1912).

[3] (*a*) F. M. Jaeger, "Temperature Coefficient of Free Molecular Surface Energy of Liquids between 80°C and 1650°C," *Z. anorg. allgem. Chem.*, **101**, 1–214 (1917).

(*b*) F. M. Jaeger, Optical Activity and High Temperature Measurements. McGraw-Hill Book Co., Inc., New York, 1930; *Ceram. Abs.*, **10** [7] 527 (1931).

[4] A. A. Griffith, "Phenomena of Flow and Rupture in Solids," *Phil. Trans. Roy. Soc.* [London], **A221**, 163 (1920).

[5] E. W. Washburn and E. E. Libman, "Viscosities and Surface Tensions of Soda-Lime Glasses at High Temperatures," *Univ. of Ill. Eng. Expt. Sta. Bull.*, No. 140, pp. 53–71 (1924); *Ceram. Abs.*, **3** [12] 342–44 (1924).

[6] W. B. Pietenpol, "Surface Tension of Molten Glass," *Physics*, **7** [1] 26–31 (1936); *Ceram. Abs.*, **15** [8] 235 (1936).

[7] (*a*) C. W. Parmelee and C. G. Harman, "Effect of Alumina on the Surface Tension of Molten Glass," *Jour. Amer. Ceram. Soc.*, **20** [7] 224–30 (1937).

(*b*) C. W. Parmelee and K. C. Lyon, "Maximum Bubble Pressure (Jaeger); Method for Measurement of Surface Tension of Molten Glass," *Jour. Soc. Glass. Tech.*, **21** [83] 44–52 (1937).

(*c*) W. Hänlein, "Relation of Specific Gravity of Glass to Temperature," *Glastech. Ber.*, **10** [3] 126–30 (1932); *Ceram. Abs.*, **11** [6] 355 (1932).

In general, the high viscosities of the molten liquid exert too great a damping effect on the weighing balance when measuring densities by loss in weight of an immersed piece of platinum. Some of the results reported in Washburn and Libman's paper are probably in error; in the case of one glass, an increase in density with increase in temperature is reported. The densities at room temperatures of sodium-silicate glasses of a composition, such as that used by Washburn and Libman, however, have been determined accurately[8]; reasonably good coefficient-of-expansion data over at least a portion of the heating range are available.[8] From these two sets of data, it is possible to deduce that the density data at high temperatures are probably not in error by more than 5 to 10%.

(3) Discordant Surface-Tension Values

The recent work of Pietenpol[6] and of Parmelee and Harman[7(a)] as well as deductions which are to be made on the basis of Jaeger's work later in this paper indicates that Washburn and Libman's surface-tension data are in error by 40 to 50%. The purported agreement of Washburn and Libman's results with data given by Tillotson[2] bears little weight; Tillotson points out that his own method, when used on liquids at room temperatures, yields values approximately one-half that of the absolute value. See also a discussion on the drop-weight method by Rideal.[9]

III. The Sessile-Drop Method

Previous investigations employing the sessile-drop method[10] at high temperatures have indicated the desirability of making further studies. On the basis of room-temperature investigations, this method is known to lack the precision possessed by other methods[11]; it is, however, a true static method.

The determination of the surface tension by means of the sessile-drop method is accomplished by equating the hydrostatic pressure of the liquid at any point to the excess pressure due to the curvature and tension of surface at the point in question; this latter pressure is given by

$$p = T\left(\frac{1}{R_1} + \frac{1}{R_2}\right). \qquad (1)$$

Where p = excess pressure.
T = surface tension.
R_1 and R_2 = two principal radii of curvature.

For a development and further discussion of this equation, refer to Adam.[12] The hydrostatic pressure due to the liquid is given by

$$p = g\sigma z + c. \qquad (2)$$

Where p = pressure.
g = coefficient of acceleration of gravity.
z = ordinate giving depth below apex of the drop (see Fig. 1).
σ = density of liquid.
c = some constant.

The equation of the equilibrium surface will then be given by

$$T\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = g\sigma z + c. \qquad (3)$$

The two radii of curvature can be described as in Fig. 1, $\rho\ (=R_1)$, operating in the plane of the paper, and $\frac{x}{\sin\phi}(=R_2)$ rotating about the vertical axis of symmetry, z. x is the horizontal coördinate

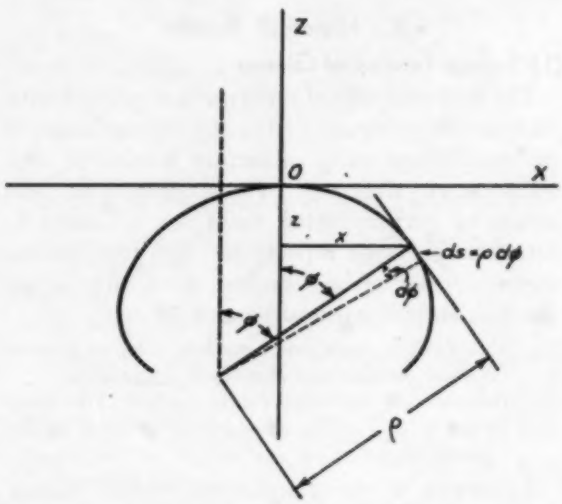

FIG. 1.—Theoretical form of meridional section of a sessile drop.

of the point on the meridional section in question and ϕ, the angle which the normal to the surface makes with the axis of revolution, z.

[8] Glastechnische Tabellen, pp. 139, 171, 221, 222. Edited by Wilhelm Eitel, Marcello Pirani, and Karl Scheel. Julius Springer, Berlin, 1932.
[9] E. K. Rideal, Introduction to Surface Chemistry, p. 13. Cambridge Univ. Press, 1930.
[10] See footnote references 1 and 4.
[11] F. Bashforth and J. C. Adams, An Attempt to Test Theories of Capillarity. Cambridge Univ. Press, 1883.
[12] N. K. Adam, Physics and Chemistry of Surfaces, pp. 12–14. Oxford Univ. Press, N. Y., 1930; *Ceram. Abs.*, 9 [10] 887 (1930).

(1) Approximation Formulas

Quincke[1] considered that with large drops $\frac{x}{\sin\phi}$ would be so large compared with ρ that the term $\frac{1}{R_2}$ could be neglected. His treatment leads to

$$\frac{g\sigma z^2}{2T} = 1 - \cos\phi, \tag{4}$$

or, in the special case where $\phi = 90°$,

$$T = \frac{g\sigma z^2}{2}. \tag{5}$$

The choice of the proper sized drop which will justify the application of such an approximation in calculating the surface tension is (paradoxically) dependent on the magnitude of the surface tension and the density of the liquid in question. The error introduced by using the approximation formula will be discussed in connection with the data. Other approximation formulas have been proposed by Worthington,[13] Lohnstein,[14] Porter,[15] Ferguson,[16] and Dorsey.[17]

(2) Bashforth and Adams' Integration[11]

Equation (3) may be written as

$$\frac{1}{\rho} + \frac{\sin\phi}{x} = \frac{c + g\sigma z}{T}. \tag{6}$$

Bashforth and Adams defined a quantity, $\beta = \frac{g\sigma b^2}{T}$, where b is a unit of length. They prepared an elaborate set of tables listing β in terms of x/b and z/b for various values of ϕ. For the special case where $\phi = 90°$, β values are listed as a function of x/z (see section on Calculations, p. 201).

(3) Calculation of Density

By definition, the density is simply the weight per unit volume. The weight of a drop of glass can be determined when cold; the volume of the hot drop can be calculated using the tables of Bashforth and Adams. It may be shown that

$$V = \frac{\pi b^3 x^3}{\beta}\left\{\frac{2}{b} - 2\frac{\sin\phi}{x} + \frac{\beta z}{b^3}\right\}. \tag{7}$$

Where β and b = same quantities defined in section (2).
x = distance NE (see Fig. 2).
z = distance NA.
ϕ = angle indicated at point D, called the contact angle.

If these calculations yield a reasonable value for density, there is reason to believe that the surface-tension data calculated from the same β and b terms will be reasonable.

(4) Calculation of Surface Area[5]

In a consideration of the possible losses that can result from volatilization from a sessile drop, it is necessary to have a knowledge of the surface exposed. By referring to Fig. 1, it can be shown that

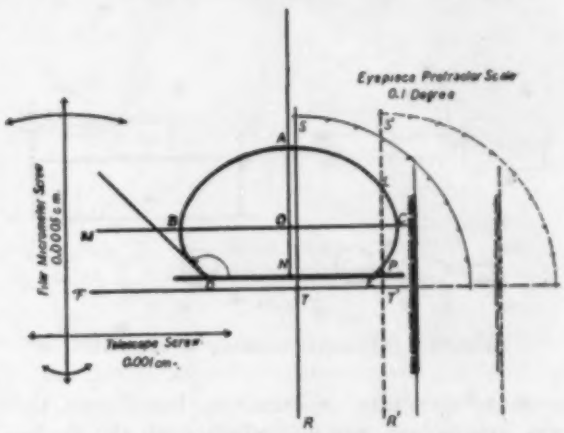

FIG. 2.—Sketch of sessile drop as it appears when viewed through telescope.

$$S = 2\pi\int_0^{\phi'}\left[\frac{\left(\frac{x}{b}\right)b^2}{2 + \beta\left(\frac{z}{b}\right) - \frac{\sin\phi}{\left(\frac{x}{b}\right)}}\right]d\phi. \tag{8}$$

Where ϕ' = value of contact angle at D (see Fig. 2) when the drop is in equilibrium.
Values of x and z = NE and AN, respectively (see section on Calculations).

IV. Apparatus

(1) Direct Observation

In one of the earlier determinations of surface tension at high temperature using the sessile-drop method, the necessary measurements were made on the cold drop.[1] Assumptions had to be

[13] A. M. Worthington, "Error Involved in Quincke's Method of Calculating Surface Tensions from Dimensions of Flat Drops and Bubbles," *Phil. Mag.*, [5] **20**, 51–66 (1885).
[14] T. Lohnstein, *Wied. Ann.*, **53**, 1062 (1894); **54**, 713 (1895).
[15] A. W. Porter, "Calculation of Surface Tension from Experiments: I, Sessile Drops," *Phil. Mag.*, [7] **15**, 163–70 (1933).
[16] (*a*) A. Ferguson, "Theoretical Shape of Large Bubbles and Drops with Other Allied Problems," *Phil. Mag.*, [6] **25**, 507–20 (1913); "Surface Tensions of Liquids in Contact with Different Gases," *ibid.*, [6] **28**, 403–12 (1914).
(*b*) A. Ferguson, Reports on Progress in Physics, pp. 30–42. Cambridge Univ. Press, 1934.
[17] N. E. Dorsey, "New Equation for Determining Surface Tension from the Form of a Sessile Drop or Bubble," *Jour. Wash. Acad. Sci.*, **18** [19] 505–509 (1928); *Ceram. Abs.*, **8** [2] 148 (1929).

made of the change in shape on cooling, but it is desirable to investigate the actual change that does take place on cooling.

In order to make a determination of the volume at the high temperature, as described in the section on density, ((3), p.195) it is necessary to view the whole of the drop directly at high temperature; no portion of the drop can be submerged in the supporting plaque.

(2) Vacuum and Controlled Atmosphere

The work of Washburn, Footitt, and Bunting[18] as well as that of Dalton[19] has revealed the existence of large amounts of dissolved gases of various kinds in the glass. Observations on the drop while in vacuum might be considered desirable because of this fact. Iredale,[20] however, by

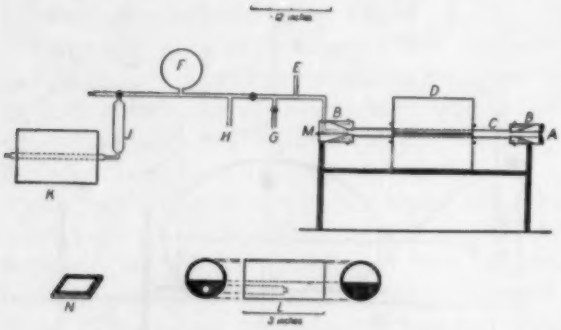

FIG. 3.—Schematic drawing of apparatus.

room-temperature experiments, has shown that the atmosphere has no influence on the surface tension if the gas is not too soluble or does not react with the surface. Because of the desire to control the atmosphere in another set of experiments reported in Part II of this paper, a high vacuum feature was incorporated in the apparatus.

(3) Description of Apparatus

A schematic drawing of apparatus is given in Fig. 3. It embodies the principle of making the observations on the outline or relief of a glowing drop against a cold background described by Barrett[21] and later used by Barrett and Taylor[22] and by Taylor.[23] This method of illumination is in direct contrast to that used by Wark,[24] Bartell,[25] and others, where the background is illuminated to establish the cold-drop or bubble relief. Observations of the interior of the vacuum-tight Champion sillimanite 6060 refractory muffle, *C*, were made through a Wilson heat-treated goggle lens, *A* (having parallel surfaces), clamped and sealed by dental dam to the male elements of the brass bearing, *B*. The muffle was sealed into a circular groove in the water-cooled female element of this same brass bearing, *B*, by means of De Khotinsky cement. These brass bearings, lubricated with Lubriseal, allowed rapid entrance and sealing; they also permitted a means to rotate the muffle about a horizontal axis for leveling purposes while under high vacuum.

The glass system was sealed by means of De Khotinsky cement into a circular groove in the male element of the second brass bearing, *B*. The framework on which the furnace, *D*, and bearings, *B*, were mounted was fastened rigidly to the same bench and pipe as that on which the glass was mounted so that stresses on this seal were eliminated.

The high vacuum system attached at *G* through a mercury seal stopcock consisted of a mercury diffusion pump backed by a Cenco Hyvac oil pump. A McLeod gage for measuring high vacuum was attached at *E*.

A simple closed-end mercury manometer capable of measuring pressures ranging from 0.1 to 850 millimeters of mercury was attached at *H* and used to indicate the amount of purified gas in the two-liter reservoir flask, *F*. This reservoir at a slight positive pressure allowed the rapid establishment of a pressure of one atmosphere of

[18] E. W. Washburn, F. Footitt, and E. N. Bunting, "Dissolved Gases in Glass," *Univ. of Ill. Eng. Expt. Sta. Bull.*, No. 118, pp. 7–32 (1920).

[19] R. H. Dalton, "Extraction and Analysis of Gases from Glass," *Jour. Amer. Chem. Soc.*, **57** [11] 2150–53 (1935); *Ceram. Abs.*, **15** [9] 271 (1936).

[20] T. Iredale, "Adsorption from the Gas Phase at a Liquid-Gas Interface," *Phil. Mag.*, [6] **48**, 177–93 (1924); [6] **49**, 603–27 (1925).

[21] E. P. Barrett, "Furnace for Measurement of Coal-Ash Softening Temperature," paper presented at Thirty-Eighth Annual Meeting of A.S.T.M., June, 1935.

[22] E. P. Barrett and J. A. Taylor, "New Method for Studying Flow Characteristics of Glasses and Slags at Elevated Temperatures," *Jour. Amer. Ceram. Soc.*, **19** [2] 39–44 (1936); discussion, *ibid.*, **21** [6] 213–15 (1938); this issue.

[23] N. W. Taylor, "Adherence of Glass to Metals," *Glass Ind.*, **16** [8] 243–46 (1935); *Ceram. Abs.*, **14** [10] 240 (1935).

[24] Ian W. Wark, "Physical Chemistry of Flotation: I, Significance of Contact Angle in Flotation," *Jour. Phys. Chem.*, **37** [5] 623–44 (1933); *Ceram. Abs.*, **12** [10–11] 399 (1933).

[25] F. E. Bartell and H. H. Zuidema, "Wetting Characteristics of Solids of Low Surface Tension, Such as Talc, Wax, and Resins," *Jour. Amer. Chem., Soc.*, **58**, 1449–54 (1936).

purified gas within the previously evacuated furnace muffle (capacity 1 liter). A drying tube, *J*, contained activated alumina. The furnace, *K*, heated copper filings to 500°C to remove oxygen from the nitrogen gas.

The resistance furnace, *D*, used in heating the central portion of the long muffle was nichrome and of split-wound construction. It produced a uniformly heated section at the center and allowed removal of the muffle without detachment of the bearings.

Water-cooled slide wire resistances in series with the furnace windings provided a means of manual control. The low temperature coefficient of surface tension,[26] combined with lack of precision inherent in the sessile-drop method, caused any more accurate temperature control to be superfluous.

The supporting plaque, *N*, for the glass drop was made of a piece of electrode graphite $^3/_{16}$ by $1^1/_2$ by 1 inch. It was plane-polished by fine emery paper, followed by smooth paper. To prevent the bead from crawling off the surface onto the refractory muffle, a moat, $^1/_8$ by $^3/_{16}$ inch, was cut out of the plaque with a razor blade.

The supporting plaque was in turn placed in the center of the refractory canopy and plaque support, illustrated in Fig. 3 by *L*. This canopy was made from a skeleton of Babcock and Wilcox No. K-30 insulating brick dressed with a slurry of Alundum cement. The hole projecting halfway into the base of the canopy served as a haven for a platinum-platinum 10% rhodium thermocouple. The wires were insulated by porcelain spaghetti inclosed within fused silica (Amersil) tubing. The thermocouple lead was made vacuum-tight by a De Khotinsky seal at *M*, and measurements of the thermocouple voltage were made on a type-K potentiometer. The silica tubing served as a convenient stop to locate the position of the refractory canopy. A hooked rod was used to pull the canopy to the open end at *A* for placing new specimens.

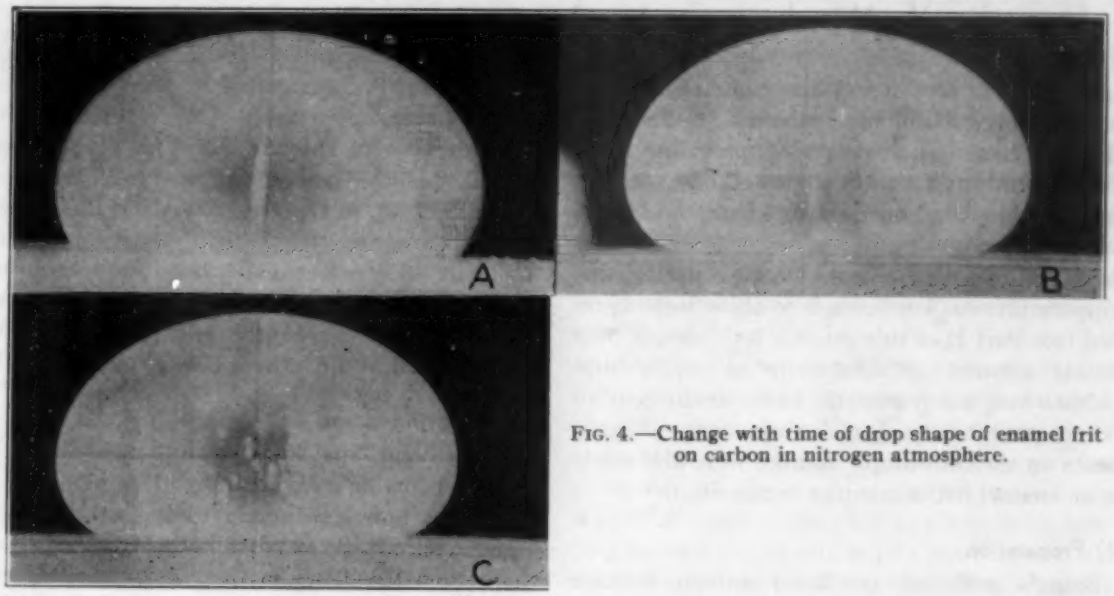

FIG. 4.—Change with time of drop shape of enamel frit on carbon in nitrogen atmosphere.

The direct measurements on the molten bead were made through *A* (Fig. 3) by means of an optical system composed of a low power (10 ×) short focus (60 cm.) telescope* mounted in a horizontal slide with micrometer (telescope) screw; a special protractor scale was attached to the filar micrometer eyepiece of the telescope. In Fig. 2, *STR* and *FT* represent the principal cross-hairs of the eyepiece which can be rotated about the point, *T; MOC* represents the double cross-hairs of the filar micrometer screw set to measure vertical distances. The black scale with which they intersect at the edge of the field of vision gives a qualitative idea of their positions. The

[26] See footnote references 3, 4, 5, and 6.

* Built by Gaertner Scientific Co., Chicago, Ill.

smallest marked division on each screw is indicated at the left in the diagram. The Leica pictures for record purposes were taken through the telescope. Measurements on the enlarged print were made with a millimeter scale (Fig. 4 *C*). The dimensions *BC* and *AN* (Fig. 2) of the cold drop were measured with micrometer calipers.

V. Materials

(1) Choice

The surface tensions of the molten materials, sodium fluoride,[3] lithium metaborate,[3] and sodium silicate,[5] have been measured previously and offered a means to check the methods used by Jaeger and by Washburn and Libman. A sodium-silicate composition, *ca.* 42 wt. % Na_2O and 58 wt. % SiO_2, was chosen because its liquidus temperature was low enough to allow melting on gold (see Part II of this paper); its viscosity (650 poises) allowed establishment of equilibrium within a long but reasonable time; devitrification did not produce any obstacles in making measurements on the cold drop. Studies were also made on an enamel frit of complex composition.

(2) Preparation

Baker's analyzed, powdered sodium fluoride was melted in a platinum crucible. Solidification of the melt yielded crystalline aggregates which could be handled as single massive pieces.

Baker's C.P. boric acid was dehydrated as well as possible by heating to 1400°C in a platinum crucible. On cooling, a weighed quantity of this anhydrous boric oxide was placed in a platinum crucible, and lithium carbonate (Baker's C.P.) was added to yield the lithium-metaborate composition.

The melting was carried out carefully (maximum temperature 950°C) to prevent noticeable losses of lithium oxide. This melt devitrified easily, and crystalline aggregates were selected for surface-tension studies.

Pure quartz (converted to cristobalite by heating) was kindly furnished by Bair and is from the same lot he used in the preparation of lead silicates.[27] Baker's analyzed sodium carbonate was intimately mixed with the cristobalite and heated slowly in the platinum crucible. The glass was fined at 1200°C. It was removed, ground, and remelted twice to aid in establishment of homogeneity. The analysis for silica was carried out as described by Hillebrand.[28]

The enamel frit was from a commercial lot and the chemical composition is approximate, furnished by the manufacturers, and is listed in Table III.

VI. Procedure

(1) Placement of Specimens

A weighed quantity of the irregular-shaped piece of solidified compound or glass was placed on the carbon supporting plaque, *N*, resting in the refractory plaque support, *L*. This plaque support, *L*, was then carefully pushed from the open end, *C* (Fig. 3), to the center of the cold furnace muffle. A strong white light above the glass tubing at *M-B* reflected light into the interior of the muffle and made the specimen stand out in relief; this was of great assistance in adjusting the specimen within the interior of the cold muffle.

(2) Removing Gases

To prevent the later disturbances by gas evolution coming from the supporting plaque and passing as bubbles directly through the molten liquid, as much gas as possible was removed from the carbon block before the compound or glass could flow. In general, this was accomplished by keeping the system under vacuum for twelve hours at a temperature just below the melting point of the compound. It was found advantageous to pre-melt the desired quantity of the glass in a vacuum on a piece of platinum foil. After cooling in vacuum, the hemispherical shape (see Part II) could be removed from the platinum foil and the apex of the drop placed in contact with the carbon.

(3) Time for Equilibrium

After the preliminary twelve-hour heat treatment, the furnace was brought to the desired temperature as rapidly as possible. In the case of the fluid melts, such as sodium fluoride and lithium metaborate, it was possible to record equilibrium measurements almost immediately on melting. The volatilization losses of sodium fluoride necessitated rapid readings. With the more viscous melts, such as the enamel frit and

[27] G. J. Bair, "Constitution of Lead Oxide-Silica Glasses: I–II," *Jour. Amer. Ceram. Soc.*, 19 [12] 339–58 (1936).

[28] W. F. Hillebrand, "Analysis of Silicate and Carbonate Rocks," *U. S. Geol. Surv. Bull.*, No. 700, p. 97 (1919).

sodium-silicate glass, time was required to establish the true equilibrium sessile-drop shape from the original irregular-shaped solid. In general, the apex of the melts considered here assumed a shape nearly that of equilibrium within one to two hours after the furnace had reached the desired temperature. The adjustment to give the final equilibrium contact angle at the base and the necessary complete symmetry about the vertical axis was slower. An inverted drop as mentioned in the previous section helped to speed up the attainment of this equilibrium. The obtuse contact angle of melts on carbon is thus approached from the side of an angle of 180°, and the portion close to the original apex of the inverted drop possesses the circular symmetry about the vertical axis. Pictures of the enamel frit on carbon in Fig. 4 illustrate the change taking place at the contact plane. The general procedure was to begin count of time about two hours after the furnace had reached the desired temperature. At this point, nitrogen was allowed to enter the furnace muffle.

VII. Measurements

(1) Cold Drop

The derivation of the original equation relating surface tension and density assumes a vertical axis of symmetry through the center of the drop. In the case of viscous melts, it was necessary to verify the attainment of this symmetry by making measurements of the maximum diameter at various points on the sessile-drop periphery after cooling to room temperature.

The previous investigations of the sessile-drop method by Quincke[1] necessitated assumptions of the behavior of the drop shape on solidification. For this reason, it was interesting to compare some of the dimensions of a cold drop with those of the molten drop. The dimensions, AN and BC (Fig. 2), were conveniently determined with micrometer calipers.

(2) Method Used to Obtain Values of b

The choice of the points on the meridional section on which to focus the measuring instruments is the source of major error in determining surface tension by the sessile-drop method (frequent references will be made to Fig. 2).

The measurements AO and OC determine a ratio, $OC/AO = x/z$, from which the value of β is obtained by use of tables (see section on Calculations). Using this value of β, it is possible to go to another portion of the tables and obtain values of x/b and z/b for the angle, $\phi = 90°$; substituting the above values of x and z measured at $\phi = 90°$, a value for b is obtained, which is the radius of curvature of the apex.

The distance, x $(=OC)$, can be determined quite accurately for it is relatively easy to choose the setting at which the cross-hairs, $S'T'R'$, become tangent to the image of the drop. It is rather difficult, however, to choose the point along the arc, LCP, at which the cross-hairs are tangent to the image of the surface, and for this reason the value of z $(=AO)$ becomes the source of error. This difficulty was recognized by Bashforth and Adams,[11] and the disagreement in their data on measured values of the surface tension of various sized drops of mercury is attributed to this cause. Volkmann[29] has discussed this source of error in more detail. Dorsey[17] has developed an empirical equation to be used in making measurements involving a tangent to an image of the surface at the point where $\phi = 45°$. Though this method is undoubtedly better, it is dependent on a previous knowledge of the range of surface tension and density in making the choice of a properly sized drop because the equation does not hold over the whole range. Mack and Lee[30] employ an approximation equation developed by Verschaffelt[31] which allows them to determine the value of b from a knowledge of the maximum radius, x, and the surface tension and density of the liquid in the drop. This, of course, presumes first of all that independent measurements are possible on the surface tension and density and that the approximation equation is applicable to the drop size chosen.

Ophthalmometric methods, successfully applied by Siedentopf[32] and Lohnstein[14] in the case of molten metals, are not applicable to glass because of its low reflectivity.

In the face of these arguments, inasmuch as the surface tension and density are to be determined

---

[29] P. Volkmann, *Wied. Ann.*, **17**, 378 (1882).

[30] G. L. Mack and D. Lee, "Determination of Contact Angles from Measurements of Dimensions of Small Bubbles and Drops: II, Sessile Drop for Obtuse Angles," *Jour. Phys. Chem.*, **40**, 169–76 (1936).

[31] J. Verschaffelt, "Shape of Small Drops and Gas Bubbles," *Proc. Acad. Sci. Amsterdam*, **21**, 357–65 (1919); "Measurement of Surface Tensions by Means of Small Drops or Bubbles," *ibid.*, pp. 366–74; "Shape of Large Liquid Drops and Gas Bubbles and Use Made of Them for Measurement of Capillary Constants," *ibid.*, 836–49.

[32] H. Siedentopf, *Wied. Ann.*, **61**, 235 (1897).

from the measurements made, the best course seemed to be that of making as accurate measurements as possible of the distances, AO and OC. To facilitate the choice of the proper tangency point, the following procedure was used. The vertical cross-hairs, $S'T'R'$, were so placed on the image of the drop as to cut off a segment of arc, LCP. The micrometer cross-hairs, BOC, were then adjusted so as to bisect the arc, and this process continued until the vertical cross-hairs coincided with the point of tangency. Using this method, remarkably good checks may be obtained on observed values. A repetition of the process on the diametrically placed tangent point leads, in general, to a measurement in good agreement with the first.

In one case, a photograph of the equilibrium drop (shown in Fig. 4*C*) was enlarged and mounted on a drawing board so that the supporting plane under the drop was perfectly horizontal. Using a right-angled triangle, the arc was segmented in a manner similar to that described under the manipulation of the telescope. The points of maximum diameter chosen on the two sides were in remarkably good agreement with a plane parallel to the base. By means of dividers and a millimeter scale, the distances, AO and OC, were determined; the value of their ratio compared well with that determined directly by telescope measurements. To get absolute values, it is necessary to know precisely the magnitude of the enlargement.

In order to make the calculations necessary for volume determinations as well as to calculate the angle of contact, it is necessary to have a measurement of the height, $z(=AN)$, of the drop above the supporting plane as well as a measure of its radius, $x(=NE)$, at the supporting plane. β and b are determined from the measurements described in the previous part. Accepting the value of β and b so obtained, and using the z distance corresponding to AN and the x distance corresponding to NE, the angle at D can be obtained from the tables by interpolation (see example in section on Calculations). An agreement between the angle obtained from x/b and z/b values, which is in further agreement with the observed angle, indicates (1) that the drop is in equilibrium in conformity with the equation and (2) that the proper points of tangency have been chosen for measurements. As has been mentioned previously, the value of b is determined from measurements on the drop at a plane above the line of contact. Visually, it is easier to identify the plane of the supporting surface than it is to choose the points at which the sessile-drop surface is tangent to this supporting plane. This is especially true in cases where there is little or no wetting with a

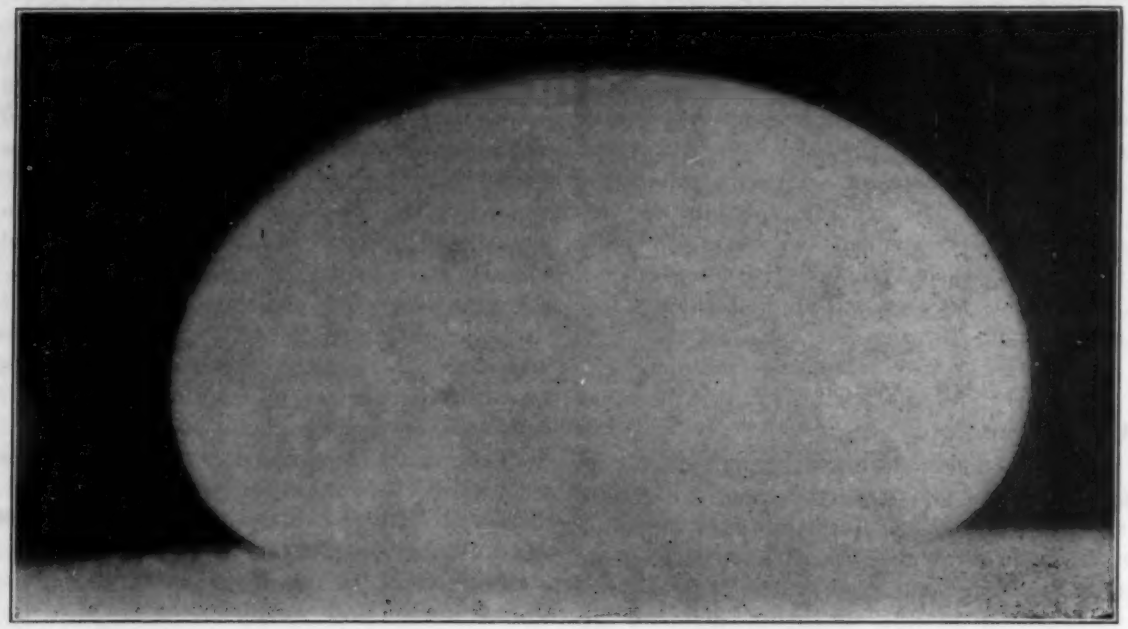

FIG. 5.—Photograph of sessile drop of sodium silicate on carbon.

subsequently large contact angle (through the liquid phase). Conversely, when the angle approaches 90°, the value of the diameter of the drop at the supporting plane can be more easily determined than the position of tangency necessary to define the diameter BC used in obtaining the value of b. Granting that the value of b, determined by the above method, is correct, it follows that in the case of large contact angles the values calculated from z/b values are of more weight than those obtained from x/b values. Agreement between observed values and those calculated from x/b, however, indicates that the proper points of tangency on the supporting plane have been chosen.

VIII. Typical Calculations

(1) Bashforth and Adams' Tables

(*a*) *To Obtain* $\frac{g b^2}{\beta}$: The calculations are illustrated by an actual example using only the pertinent sections of Bashforth and Adams' tables.

Note: More complete copies (pp.1–15) have been made by Bibliofilm Service, Library of U. S. Department of Agriculture, Washington, D. C., and are included with the original thesis, copies of which are filed at the Pennsylvania State College Library.

By the method of differences, it was established that a linear interpolation would yield the accuracy warranted by the measurements.

The measurements on the sodium-silicate drop (41.6 wt. % Na_2O) on carbon (Fig. 5) were taken after 86 hours at 1022°C.

$x = AO = 0.3782$ cm.
$z = OC = 0.4891$ cm.
$\frac{AO}{OC} = 1.2932 = \frac{x}{z}$, when $\phi = 90°$.

TABLE I

PORTION OF BASHFORTH AND ADAMS' TABLES RELATING VALUES OF β TO $\left(\frac{x}{z}\right)_{\phi=90°}$

β	0.0	0.2	0.4	0.6	0.7	0.8
0	1.00000	1.04149	1.07589	1.10542	1.11880	1.13140
1	1.15466	1.17576	1.19508	1.2129	1.22138	1.22953
2	1.24507	1.25967	1.27345	1.28650	1.29278	1.29890
3	1.31072	1.32201	1.33283	1.34320	1.34824	1.35318
4	1.36278	1.37204	1.38100	1.38963	1.39386	1.39802

Reference is now made to the Bashforth and Adams' tables (p. 1)[11] as given in Table I.

By interpolation, the following value is obtained:

$$\beta = \frac{g\rho b^2}{T} = 2.700.$$

Table II gives a portion of Bashforth and Adams' tables (p. 5).[11]

TABLE II

PORTION OF BASHFORTH AND ADAMS' TABLES GIVING VALUES OF $\frac{x}{b}$ AND $\frac{z}{b}$ IN TERMS OF β AND ϕ

β	2.5		3.0		3.5	
ϕ	x/b	z/b	x/b	z/b	x/b	z/b
5°	0.08695	0.00379	0.08691	0.00379	0.08687	0.00379
90°	0.79275	0.61931	0.77074	0.58803	0.75137	0.56154
160°	0.58518	0.95113	0.57898	0.89467	0.57223	0.84798
165°	0.56364	0.95793	0.55901	0.90097	0.55353	0.85390
170°	0.54240	0.96265	0.53927	0.90535	0.53500	0.85802

By linear interpolation, $\phi = 90°$, $\beta = 2.700$, $x/b = 0.7839$, and $z/b = 0.6068$.

From the previous measurements, values were obtained for $x(=OC)$ and $z(=AO)$ of 0.3782 and 0.4891 cm., respectively. This leads to values of $b = 0.6238$ and 0.6232 cm., with a mean of 0.6236 cm. By combining this with previous data, the following equation is obtained:

$$T = \frac{g\rho b^2}{\beta} = 141.2\sigma.$$

(*b*) *To Obtain Angle:* The measurements $z(=AN)$ and $x(=NE)$ are 0.5846 and 0.3490 cm., respectively. Accepting the value $b = 0.6236$ cm., values are obtained as follows:

$$x/b = 0.5597 \text{ and } z/b = 0.9376.$$

Accepting the value of $\beta = 2.700$ and referring to Table II, by interpolation it is found that

the angles, ϕ, given by the x/b and z/b values, are 165.5° and 167.0°, respectively. This compares favorably with the observed values (Fig. 5).

(*c*) *To Obtain Volume:* Referring to equation (7) and using the values determined above,

$x = 0.3490 = AN$
$z = 0.5846 = NE$
$b = 0.6235$
$\beta = 2.700$
$\phi = 166°.$

The volume is calculated to be equal to 0.324 cubic centimeters.

(*d*) *To Obtain Density:* The weight of the cold glass drop was 0.7031 gram. Using the volume determined in (*c*), the value for density

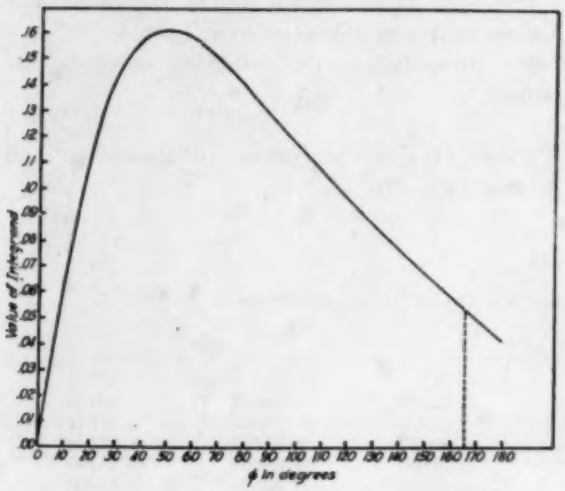

FIG. 6.—Curve used in evaluating surface area of drop shown in Fig. 5.

equals 0.7031/0.324 = 2.17 grams per cubic centimeter.

(*e*) *To Obtain Surface Tension:* By combining these results for β, b, and σ, it is found that $T = g\sigma b^2/\beta = 306$ dynes per centimeter.

(*f*) *To Obtain Surface Area:* Making use of the values, $x/b = 0.5597$, $z/b = 0.9376$, and $\beta = 2.700$, the integrand of equation (8) was evaluated for every 5-degree interval of ϕ. These values are plotted in Fig. 6. The surface exposed by the drop in question (Fig. 5) is then 2π times the area under the curve between the origin and the angle, $\phi' = 166°$. Using Simpson's rule, the value of the integral between the limits, $\phi = 0°$ to $\phi = 160°$, was determined as $1.97/2\pi$ square centimeters. Applying the data of Preston and Turner[23] on loss of sodium oxide from sodium silicate melts, a loss of 0.0118 gram of Na_2O would be expected out of the original 0.7031 gram from the 2 square centimeters at the end of 80 hours. Owing to the curvature of this surface, as compared with the plane surfaces used by Preston and Turner, the application can not be too rigorous.

(2) Approximation Formulas of Quincke and Worthington

Quincke's approximation formula,[1] $T = h^2g\sigma/2$, makes use of the measurement, $h = AO$.

Worthington's approximation formula,[13] $T = h^2r\sigma g/2r + 1.218h$, makes use of the measurements, $h = AO$ and $r = OC$.

For further discussion of these formulas, see a review paper by Ferguson.[16]

IX. Data

A summary of the data is presented in Table III. The values listed under surface tension are those calculated, using the tables of Bashforth and Adams and the approximation formulas of Quincke and Worthington. The work-of-adhesion values were obtained by a relationship to be discussed later. The values of OC and AN were obtained on the molten drop; the values listed below each of these represent the percentage decrease in these dimensions on cooling. The furnace cooled to room temperature in eight hours.*

X. Discussion

(1) Change of Shape of Drop on Cooling

An examination of the data on the cold drop shows, in general, that the vertical dimension shrinks about 5 to 6%, and the horizontal dimension shrinks about 2 to 3%. These results offer an answer to questions raised by Rideal[9] and others, which to a certain extent have discredited the work of Quincke.[1] The asymmetry in contraction is probably due to asymmetry of temperature distribution within the drop as it cools through the softening range. Liquids of low viscosity and high thermal conductivity would probably show less distortion.

[23] E. Preston and W. E. S. Turner, "Volatilization and Vapor Tension at High Temperatures of the Sodium Silicate-Silica Glasses," *Jour. Soc. Glass Tech.*, **16** [63] 331–49 (1932); *Ceram. Abs.*, **12** [3] 98 (1933).

* The detailed measurements and calculations are recorded in the original thesis filed in the Pennsylvania State College Library.

(2) Comparison of Results with Those of Other Workers

Data obtained on fused sodium fluoride and lithium metaborate give surface tensions agreeing with Jaeger's results[3] within experimental error. Data on the sodium-silicate drops give values for surface tension about twice those obtained by Washburn and Libman.[5] The calculated densities on the sodium-silicate drops are smaller than those reported by Washburn and Libman[5] but do not differ by as large a percentage as do the surface tensions.

The surface tensions (surface energies) plotted in Figs. 7 and 8 are taken from data given by Jaeger.[3]

Inasmuch as liquids are likely to be comparable a few degrees from the "corresponding state" of their melting points, the surface tensions at a temperature 10° above the melting point were chosen for comparison.

If it is assumed that the ionic domains in the liquid are comparable to those in the solid crystal, the surface energies of the molten liquids may be plotted as a function of interionic distances to obtain the curves given in Figs. 7 and 8. This type of treatment is justified by the reasonable results of numerical calculations made by Born, Lennard-Jones, and others.[12] They have evaluated the surface energies of the solid alkali halides by assuming that the cohesive forces are simple electrostatic forces existing between ions of fairly definite sizes.

From crystal-structure data, it appears that the $SO_4^{=}$ group is a tetrahedron of oxygen ions with a sulfur center and that $SiO_4^{=}$ has about the same shape and size. The structures of lithium metasilicate (Li_2SiO_3) and lithium sulfate (Li_2SO_4) are different. The latter is probably an assemblage of alternate Li^+ and $SO_4^{=}$, the metasilicate is likely built up of chains or rings, made by sharing oxygen corners of tetrahedra, and these chains or rings are linked to one another by Li^+.

Jaeger has presented data for the surface energy of a series of the molten metaborates of lithium, sodium, and potassium, in which case there must be a sharing of oxygen ions between borate triangles. The surface energies of the molten sulfates as well as those of the molten metaborates of lithium, sodium, and potassium are plotted as functions of the sum of the ionic radii of discrete ionic units (Fig. 8). Neither of these relations will permit any direct conclusions as to the metasilicates, but at least the general trend of the surface energy relationships with change in ionic separation should be similar.

Jaeger has presented surface-tension values for lithium metasilicate.[3]

If the value of surface energy, 380 ergs per square centimeter, is plotted for lithium metasili-

TABLE III

SURFACE TENSION, DENSITY, AND OTHER DATA ON SEVERAL LIQUIDS

Measurements Made in Nitrogen with Molten Drop Resting on Electrode Graphite

Compound	Temp. °C	Time	Calculated contact angle	Calculated volume (cm.³)	Density (g./cm.³)	Surface tension (dynes/cm.) Bashforth and Adams	Quincke	Worthington	Work of adhesion (ergs/cm.²)	*OC* and % decrease on cooling	*AN* and % decrease on cooling
NaF	994	30 min.	135°	1.2579	1.947*	208	118	88	61	Crystallized	
$LiBO_2$	925	41 hr.	101°	0.3868	1.77	247	159	111	199	Crystallized	
Sodium silicate (I)	997	37 hr.	135°	0.4409	2.19	312	176	121	68	0.5459 2.89%	0.5730 5.09%
†Sodium silicate (II)	1022	86 hr.	166°	0.3240	2.17	306	152	103	9	0.4891 3.64%	0.5847 5.37%
‡Enamel frit	994	72 hr.	158°	0.3206	2.29	310	159	109	22.5	0.4928 1.93%	0.5718 6.01%

* From Jaeger's data.

† Fig. 5; composition Na_2O 41.6, SiO_2 58.4%.

‡Fig. 4.

Composition (%)		Composition (%)	
SiO_2	53.6	ZnO	5.8
Na_2O	15.6	B_2O_3	10.3
K_2O	4.0	Al_2O_3	5.1
CaO	0.4	Fe_2O_3	Tr.
BaO	2.7	ZrO_2	2.3

cate against the sum of the radii of lithium and silicate ions, one fixed point of a curve will be obtained (Fig. 9). Using the relationships given by the curves for the metaborates and the sulfates, the surface-energy value for the sodium metasilicate should be of the order of magnitude of 300 to 350 ergs per square centimeter. This is to be compared with the value (312) obtained for the sodium-silicate composition by the sessile-drop method.

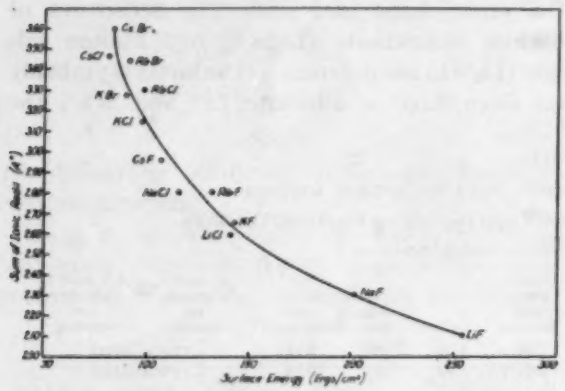

FIG. 7.—Data obtained by Jaeger showing relation between ionic size and surface energy for monovalent cations and anions; radius sum ranges from 2.00 to 3.60Å.

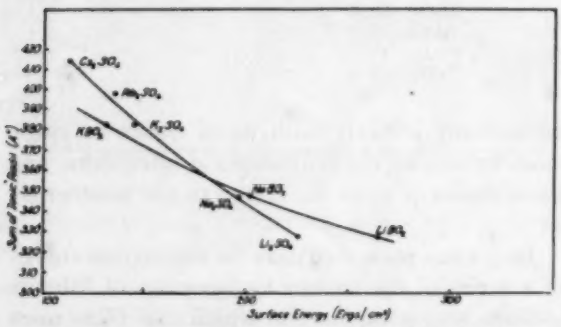

FIG. 8.—Data obtained by Jaeger showing relation between ionic size and surface energy for monovalent cations and divalent anions; radius sum ranges from 3.00 to 4.20Å.

(3) Source of Error in Washburn-Libman Data

From the foregoing arguments, two independent lines of evidence point definitely to the invalidity of the surface-tension data of Washburn and Libman, where values are given as 150 to 160 ergs per square centimeter. Because the static method they used would seem to be theoretically sound, it might be well to consider at least one of the possible sources of error.

Pietenpol[6] has suggested an error in the Washburn and Libman assumptions with regard to contact angle. The formula used in their surface-tension calculations,

$$T = \left(\frac{hgE}{2L} + \frac{hdgw}{2}\right)\frac{1}{\cos\theta},$$

gives the dependence of the surface tension on the contact angle. In order to raise the surface tension from 150 to 300 dynes per centimeter, it would be necessary to have a value of the cos θ of about 0.5 or a contact angle of around 60°, as compared with their assumed value of 0°. In Part II, it will be shown that the contact angle of a sodium-silicate glass against platinum is approximately 60° in the presence of nitrogen or *in vacuo*. This is illustrated by Figs. 1 to 6 (Part II).

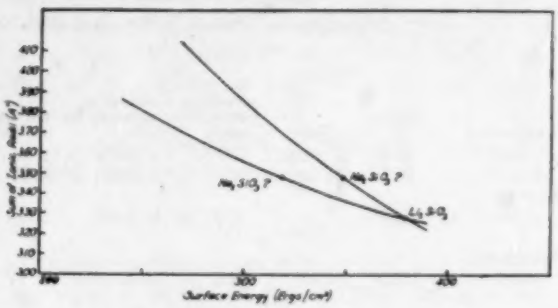

FIG. 9.—Curves used to predict surface-energy data on sodium metasilicate from Jaeger's data on lithium metasilicate and slope of Fig. 8; radius sum ranges from 3.00 to 4.10Å.

If the oxygen atmosphere above the molten glass in the experiments of Washburn and Libman were in some way removed, it would be possible to explain their relatively low results.

XI. Summary

(1) An apparatus has been described which allows linear measurements to be made directly on a sessile drop of liquid at temperatures as high as 1100°C in nitrogen or oxygen or *in vacuo*.

(2) Sessile drops at high temperatures were photographed, using the radiation from the drop itself as a source of light.

(3) By the use of tables prepared by Bashforth and Adams, the volume and surface areas of sessile drops at high temperatures have been calculated. These quantities, together with the weight of the drops, permit evaluation of the surface tensions and densities.

(4) Surface-tension data obtained by the sessile-drop method on sodium fluoride and lithium metaborate have been found to agree with data obtained by Jaeger using the maximum bubble-pressure method.

(5) Surface tension on a sodium-silicate composition (*ca.* 300 dynes/cm.) does not check with Washburn and Libman's value (*ca.* 160 dynes/cm.) obtained by the dipping-cylinder method, but is in substantial agreement with Jaeger's results.

(6) From internal evidence it is believed that the sessile-drop method leads to absolute surface-tension values correct to within 5%.

(7) The sessile-drop method is applicable to liquids having a viscosity up to 600 to 700 poises, whereas the maximum bubble-pressure method is limited to liquids with a viscosity of 50 to 70 poises. The sessile-drop method, however, lacks the precision of the maximum bubble-pressure method.

(8) Data on the contact angle of liquids on platinum indicate that Washburn and Libman probably had an atmosphere deficient in oxygen within their furnace and show that the dipping-cylinder method is unreliable unless the angle of contact is measured directly at the time and on the same surface. It can not safely be assumed to be equal to zero.

Department of Ceramics
Pennsylvania State College
State College, Pennsylvania

SURFACE PROPERTIES OF FUSED SALTS AND GLASSES: II, CONTACT ANGLE AND WORK OF ADHESION ON GOLD AND PLATINUM IN VARIOUS ATMOSPHERES

By Bennett S. Ellefson* and Nelson W. Taylor

Abstract

At 1000°C, drops of sodium silicate (42% Na_2O) resting on a gold surface showed the same contact angle *in vacuo*, nitrogen, or oxygen, but on a platinum surface they spread to a thin layer in the presence of oxygen. Lithium metaborate and an enamel cover-coat frit behaved like the sodium silicate in forming drops on platinum *in vacuo* and thin films when oxygen was present. The absolute work of adhesion was determined in several cases. This quantity is greater for the metal surfaces than for a surface of electrode graphite. The rate of spreading was shown to depend inversely on the viscosity of the liquid. Photographs are presented to illustrate these observations. Some applications are noted.

I. Introduction

Knowledge of the equilibrium contact angle at high temperatures is required in certain methods of determining the absolute value of surface tension at high temperatures. Washburn and Libman[1] assumed that this angle was zero in their work, an assumption which probably was not correct. A knowledge of the equilibrium contact angle and of the surface tension of the molten liquid permits the calculation of the "work of adhesion," *i.e.*, the amount of energy which must be expended per square centimeter in separating the molten liquid from the solid area of contact. An absolute measure of this work of adhesion is, of course, more valuable than that of the contact angle alone in determining the ultimate ability of various kinds of glass to wet a given metal.

II. Measurement of the Angle of Contact

(1) Direct Observation

The angle of contact can be obtained by direct measurement on the image of a meridional section of a sessile drop by using a protractor arrangement.[2] A type of apparatus for making such con-

* Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, the Pennsylvania State College, February, 1937. Received August 2, 1937.

[1] E. W. Washburn and E. E. Libman, "Viscosities and Surface Tensions of Soda-Lime Glasses at High Temperatures," *Univ. of Ill. Eng. Expt. Sta. Bull.*, No. 140, pp. 53–71 (1924); *Ceram. Abs.*, **3** [12] 342–44 (1924).

[2] (*a*) N. E. Dorsey, "New Equation for Determining Surface Tension from the Form of a Sessile Drop or Bubble," *Jour. Wash. Acad. Sci.*, **18** [19] 505–509 (1928); *Ceram. Abs.*, **8** [2] 148 (1929).

(*b*) A. W. Porter, "Calculation of Surface Tension from Experiments: I, Sessile Drops," *Phil. Mag.*, [7] **15** 163–70 (1933).

(*c*) Ian W. Wark, "Physical Chemistry of Flotation:

tact-angle measurements at high temperatures has been described by Barrett and Taylor[3] and later used by N. W. Taylor.[4]

(2) Calculated

The contact angle can also be calculated from the equilibrium dimensions of the drop. The advantages of this latter method have been discussed by Mack[5] and Mack and Lee.[6] The case of the calculations of obtuse contact angles has been discussed in Part I of this paper. Considering acute angles, Mack[5] has shown that as the drop size decreases its shape departs less and less from a true spherical segment. The size of drop to which such a treatment applies is, of course, a function of the density and surface tension.

In the event of the correct applicability of the spherical segment shape, the contact angle is given by

$$\theta = 2 \tan^{-1} \left(\frac{h}{x}\right)$$

Where θ = contact angle.
h = height of drop.
x = radius at base.

The volume of this same drop is given by

$$V = \frac{\pi}{6}\left(h^3 + 3hx^2\right).$$

Tables have been prepared by Mack[5] for convenience in calculating the necessary corrections to be made on angles obtained in this manner. Of two drops having the same height and base, the first a true spherical segment and the second influenced by gravity, the latter drop will have the greater volume. With a known weight of liquid (molten glass) in the shape of a gravity-affected sessile drop having an acute contact angle, the volume, as calculated on the basis of a spherical segment, will lead to too great a density. Thus an independent knowledge of the density can aid in verifying the choice of the proper sized drop.

FIG. 1.—Sodium silicate (42% Na_2O) on gold (1000°C) in (*a*) vacuum and (*b*) oxygen atmosphere.

III. Work of Adhesion

Many studies have been made on work of adhesion at room temperature. The derivation of the following relationship can be found in several publications[7]:

$$W = T(1 + \cos\theta).$$

Where W = work of adhesion.
T = surface tension of liquid being studied.
θ = angle of contact (measured through liquid phase, see Part I).

More recent publications by Wark,[8] Bartell,[9] and others carry discussions of this related field.

IV. Apparatus

The apparatus was the same as that used in the surface-tension measurements, except that when using an air or oxygen atmosphere the supporting plaque for the metals was made of fired Alundum cement instead of electrode graphite. The vac-

I, Significance of Contact Angle in Flotation," *Jour. Phys. Chem.*, **37** [5] 623–44 (1933); *Ceram. Abs.*, **12** [10–11] 399 (1933).

[3] E. P. Barrett and J. A. Taylor, "New Method for Studying Flow Characteristics of Glasses and Slags at Elevated Temperatures," *Jour. Amer. Ceram. Soc.*, **19** [2] 39–44 (1936); see also this issue, pp. 213–15.

[4] N. W. Taylor, "Adherence of Glass to Metals," *Glass Ind.*, **16** [8] 243–46 (1935); *Ceram. Abs.*, **14** [10] 240 (1935).

[5] G. L. Mack, "Determination of Contact Angles from Measurements of Small Bubbles and Drops: I, Spheroidal Segment for Acute Angles," *Jour. Phys. Chem.*, **40**, 159–67 (1936).

[6] G. L. Mack and D. Lee, "Determination of Contact Angles from Measurements of Dimensions of Small Bubbles and Drops: II, Sessile Drop for Obtuse Angles," *ibid.*, **40**, 196–76 (1936).

[7] (*a*) E. K. Rideal, Introduction to Surface Chemistry, pp. 5–7. Cambridge Univ. Press, 1930.
(*b*) N. K. Adam, Physics and Chemistry of Surfaces, pp. 173–75. Oxford Univ. Press, N. Y., 1930; *Ceram. Abs.*, **9** [10] 887 (1930).
(*c*) G. Bakker, Kapillarität und Oberflächenspannung, pp. 65–66. Handbuch der Experimental Physik, 1928.

[8] See footnote reference 2(*c*).

[9] F. E. Bartell and H. H. Zuidema, "Wetting Characteristics of Solids of Low Surface Tension Such as Talc, Wax, and Resins," *Jour. Amer. Chem. Soc.*, **58**, 1449–54 (1936).

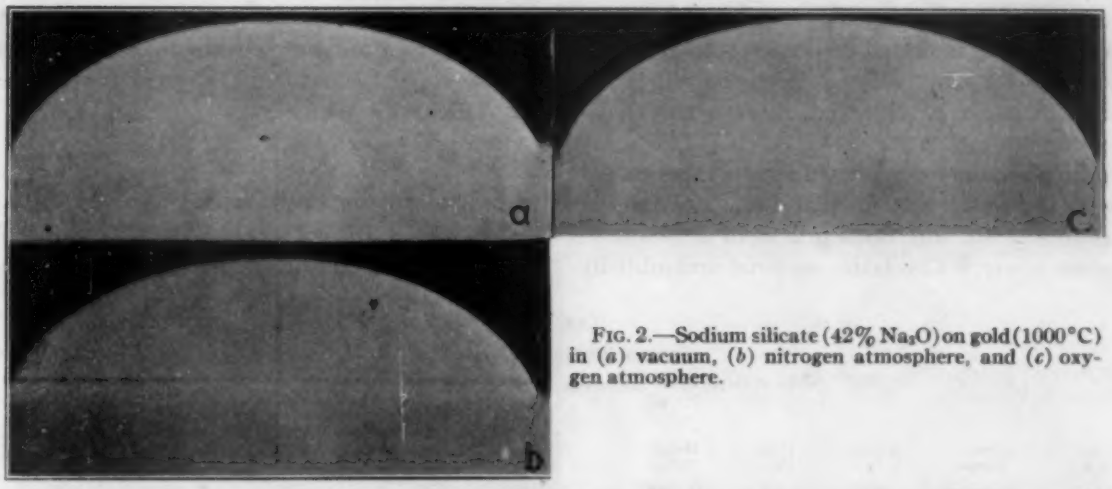

FIG. 2.—Sodium silicate (42% Na_2O) on gold (1000°C) in (*a*) vacuum, (*b*) nitrogen atmosphere, and (*c*) oxygen atmosphere.

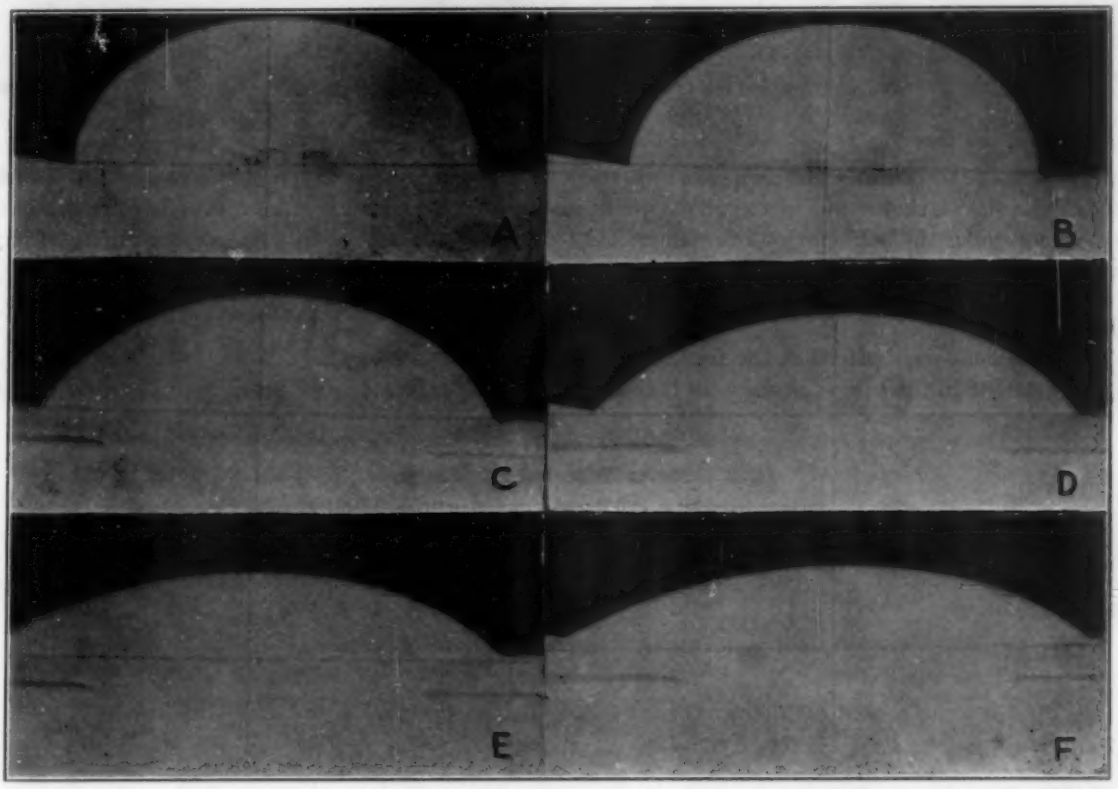

FIG. 3.—Enamel frit on platinum (1000°C) after entrance of oxygen, after successive one-minute intervals.

uum obtained with this apparatus was never more than 10^{-4} to 10^{-5} centimeter of Hg.

V. Materials

(1) Salts and Glasses

The lithium metaborate, sodium silicate, and enamel frit were from the same batches as used in the experiments on surface tension.

(2) Metals

The metals chosen were gold and platinum. Before polishing, the metals were heated in a vacuum for 12 hours at the maximum temperatures possible to remove gas from the interior of the metal. The gold metal used was in the form of a 1-inch square, 0.0015 inch thick.* Because

* Sold as 99.998% fine by Handy and Harman Co., New York, N. Y.

of its purity it was very ductile, and while being polished it was mounted on a microscope slide by means of Canada balsam. After polishing, no striations could be observed under a magnification of 450×.

Pure platinum foil was used for the experiments involving enamel frit on platinum, and later a platinum sheet was fashioned from a platinum crucible cover. This latter material undoubtedly contained some iridium. The behavior of the enamel frit on platinum foil in oxygen is in essence the same as the behavior of the sodium silicate on the platinum sheet.

(3) Procedure

The specimens were placed in the furnace muffle and brought to the proper position in the same manner as that described in the surface-tension experiments of Part I. In order to remove as much gas as possible from the metal before it was covered with any liquid, the furnace was kept for twelve hours at a temperature just below the melting points of the respective salts. In all cases, the weights of the solidified salts or glasses were determined before the experiments because the adhesion made it impossible to remove them completely afterward.

Photographs were made at suitable time intervals by a Leica camera mounted with the observing telescope. Ten to fifteen seconds were required for each exposure.

VI. Data

(1) Enamel Frit on Platinum Foil

The enamel frit was kept at 1000°C until it reached the equilibrium shape represented by the first picture in Fig. 3. Then oxygen was allowed to enter, and each picture represents the state of the drop at the end of successive one-minute intervals.

TABLE I

SODIUM SILICATE ON GOLD

Surface tension = 306 dynes/cm.; weight = 0.3491 g.

Fig. No.	Atmosphere	Temp. °C	Time (hr.)	Height (cm.)	Width (cm.)	Angle calculated	Volume calculated (cm.³)	Density calculated	Work of adhesion (ergs/cm.²)
1(*a*)	Vacuum	998	12	0.2887	1.1096	55°	0.1521	2.29	481
	Nitrogen allowed to enter just after previous reading								
	Nitrogen	1000	24	0.2870	1.1118	54°	0.1517	2.30	483
	Vacuum applied for 1 hour to remove nitrogen; then oxygen enters								
1(*b*)	Oxygen	1000	31	0.2870	1.1114	54°	0.1515	2.30	483

VII. Discussion

(1) Surface Tension

(*a*) *Contact Angle:* An inspection of the data on the contact angle of sodium silicate on platinum given in Table IV shows that in vacuum or nitrogen atmosphere the value is approximately 60°. This value, when substituted for θ in the Washburn-Libman formula,

$$T = \left(\frac{kgE}{2L} + \frac{hdgw}{2}\right)\frac{1}{\cos\theta},$$

would lead to a surface-tension value approximately twice as large as that calculated on the as-

TABLE II

SODIUM SILICATE ON GOLD

Surface tension = 306 dynes/cm.; weight = 0.5994 g.

Fig. No.	Atmosphere	Temp. °C	Time (hr.)	Height (cm.)	Width (cm.)	Angle calculated	Volume calculated (cm.³)	Density calculated	Work of adhesion (ergs/cm.²)
2(*a*)	Vacuum	996	0	0.3456	1.2558	57°	0.2356	2.54	469
	Nitrogen allowed to enter after 5 hours of vacuum								
2(*b*)	Nitrogen	1000	24	0.3445	1.2681	57°	0.2398	2 49	472
	Vacuum applied just after reading and retained for 25 hours; then oxygen allowed to enter								
2(*c*)	Oxygen	1000	50	0.3385	1.2689	56°	0.2335	2.56	471

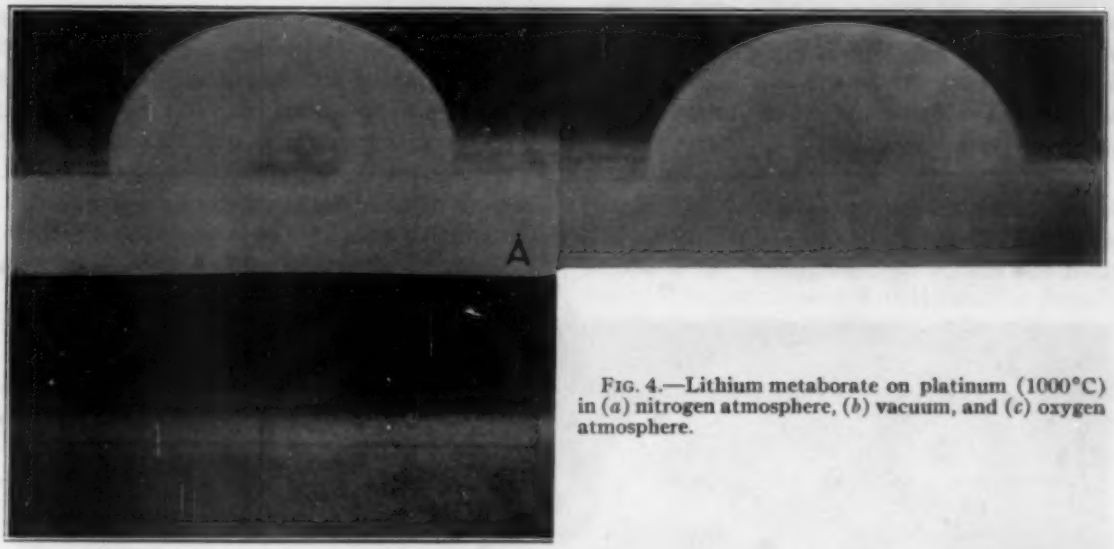

FIG. 4.—Lithium metaborate on platinum (1000°C) in (*a*) nitrogen atmosphere, (*b*) vacuum, and (*c*) oxygen atmosphere.

sumption of a contact angle, $\theta = 0°$. This 60° value of surface tension would have the same order of magnitude as that obtained by other methods. Just how the partial pressure of oxygen might have been reduced is a matter of conjecture. These considerations offer a possible (but not necessarily the only) explanation of the low results of Washburn and Libman. In making a small melt of lithium metaborate in a platinum crucible within a gas-fired furnace, it is possible to have the melt spread over the entire crucible bottom or gather into a drop as the combustion conditions are oxi-

TABLE III

LITHIUM METABORATE ON PLATINUM

Fig. No.	Atmosphere	Time	Temp. °C	Height (cm.)	Width (cm.)	Angle calculated	Work of adhesion (ergs/cm.²)
4(*a*)	Nitrogen	8 hr.	928	0.3870	0.8335	85°	*Ca.* 250
		Vacuum applied immediately after reading					
4(*b*)	Vacuum	8 hr. 15 min.					
		Oxygen allowed to enter immediately after picture recorded					
4(*c*)	Oxygen	Drop spread out and covered metal surface in less than one second after oxygen entered					

TABLE IV

SODIUM SILICATE ON PLATINUM

Surface tension = 306 dynes/cm.; weight 0.5506 g.

Fig. No.	Atmosphere	Temp. °C	Time	Height (cm.)	Width (cm.)	Angle calculated	Volume calculated (cm.³)	Density calculated	Work of adhesion (ergs/cm.²)
5(*a*)	Nitrogen	998	8 hr.	0.3580	1.2126	61°	0.2308	2.38	453
			Vacuum applied after 18 hr.						
5(*b*)	Vacuum	998	21 hr.	0.3830	1.1814	65°	0.2394	2.29	431
			Nitrogen allowed to enter after 23 hr.						
5(*c*)	Nitrogen	1000	54 hr.	0.3783	1.2046	64°	0.2439	2.26	439
6(*a*)	Vacuum								
6(*b*)	Oxygen		After 15 sec.						
6(*c*)	Oxygen		After 1 min.						
6(*d*)	Oxygen		After 2 min.						
			Vacuum applied for 12 hr						
5(*d*)	Vacuum	1000	66 hr.	0.3470	1.2694	57°	0.2416	2.28	470

dizing or reducing. This example is striking because of the rapid attainment of the equilibrium contact angle (see Fig. 4). When good oxidizing conditions are present, the contact angle is probably something approaching 0°.

(*b*) *Effect of Atmosphere:* Referring to Table II it will be noted that no appreciable change of the sodium-silicate drop shape on gold accompanied the change of atmosphere. It is almost inconceivable that the surface energies of materials so inherently different as gold and molten salts would respond in the same degree to yield equilibrium conditions which in each case would not change in the presence of nitrogen or oxygen. The logical conclusion is that neither is affected. This validates the absolute surface-tension values obtained by the use of nitrogen gas in the maximum bubble-pressure method described by Jaeger and used by Parmelee and Lyon[10] and Parmelee and Harman.[11]

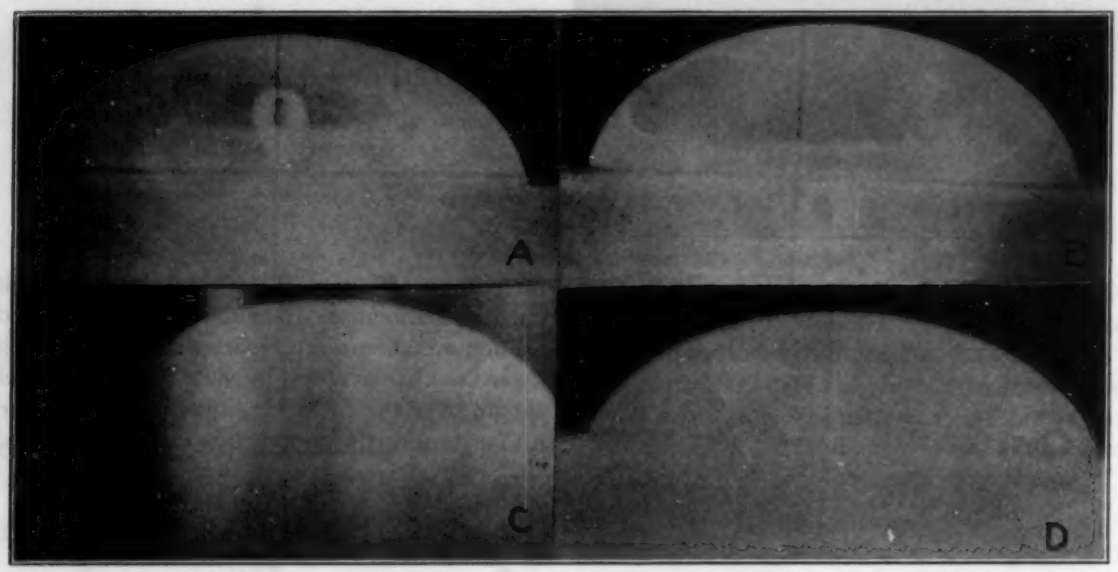

FIG. 5.—Sodium silicate (42% Na_2O) on platinum (1000°C) in (*a*) nitrogen, (*b*) vacuum, (*c*) nitrogen atmosphere, and (*d*) vacuum.

(2) Advancing and Receding Angles

Bartell and Wooley[12] point out that advancing and receding angles are probably equilibrium angles for the respective solid surfaces being considered. Thus, in the case of the receding angle, the surface having once been wet by the liquid may have undergone an inherent change to yield a surface with lower potential energy. It is entirely possible that at higher temperatures surface reorientation would take place spontaneously and it would be impossible to distinguish between advancing and receding angles. The experiments recorded in Figs. 5 and 6 demonstrate the possibility of producing solid-surface alteration reversibly in the presence of the liquid drop. More experiments of this kind would be of interest in connection with the type of studies carried on by Bartell, Culbertson, and Miller.[13]

(3) Effect of Viscosity of Melt

A comparison of Figs. 3, 4, and 6 illustrates the effect of the viscosity on the rate of attainment of equilibrium. The fluid lithium metaborate spread instantaneously over the platinum surface

[10] C. W. Parmelee and K. C. Lyon, "Maximum Bubble Pressure (Jaeger); Method for Measurement of Surface Tension of Molten Glass," *Jour. Soc. Glass. Tech.*, **21** [83] 44–52 (1937).

[11] C. W. Parmelee and C. G. Harman, "Effect of Alumina on Surface Tension of Molten Glass," *Jour. Amer. Ceram. Soc.*, **20** [7] 224–30 (1937).

[12] F. E. Bartell and A. D. Wooley, "Solid-Liquid-Air Contact Angles and Their Dependence on Surface Condition of Solid," *Jour. Amer. Chem. Soc.*, **55**, 3518–27 (1933).

[13] (*a*) F. E. Bartell, J. L. Culbertson, and M. A. Miller, "Alteration of Free Surface Energy of Solids: I, Vertical Rod Method for Measurement of Contact Angles and Preliminary Study of Effect of Heat Treatment on Magnitude of Contact Angle," *Jour. Phys. Chem.*, **40**, 881–88 (1936).

(*b*) F. E. Bartell and M. A. Miller, "II, Effect of Heat Treatment of Metals in Air," *ibid.*, **40**, 889–901 (1936).

(*c*) F. E. Bartell and M. A. Miller, "III, Effect of Heat Treatment of Metals in Vacuum and in Several Gases," *ibid.*, **40**, 902–904 (1936).

as soon as air was admitted, whereas the more viscous sodium silicate and enamel frit required several minutes to spread to the new equilibrium position.

(4) Nature of the Metal Surface

Hull and Burger[14] have indicated the significance of studies on wetting of metals by glass in connection with the problem of sealing wires into glass. The question has arisen as to whether or not it is necessary to have an oxygen atmosphere or an oxidizing agent present in the glass phase in order to secure any spreading of the glass on metallic surfaces. Because platinum and gold surfaces in many cases have been considered oxide-free, it is interesting to compare the behaviors of these metals with respect to that of a carbon surface in the presence of a glass and various gas atmospheres.

An examination of the previous section on data shows that there is a definite wetting of the gold metal as such by the molten sodium silicate. Furthermore, the degree of wetting is not significantly affected by the kind of atmosphere present. In the case of the platinum metal, there is likewise a definite tendency of the metal to be wet by the molten sodium silicate, there being no noticeable difference between the nitrogen atmosphere or vacuum. The entrance of the oxygen, however, has a decidedly marked influence in reducing the liquid-solid interfacial energy. This reaction is reversible as is shown by the restoration of the glass drop to practically its original shape by simply removing the oxygen.

(*a*) *Surface Studies on Gold:* As a result of the development of electron-diffraction methods for studying thin films,[15] there has been a renewed interest in research on the surface structure of metals. The results of these diffraction experiments in the case of polished surfaces of noble metals have been interpreted by some investigators as a confirmation of the existence of an amorphous layer about 30 to 50 Å deep or at least of a surface in a very fine state of subdivision.

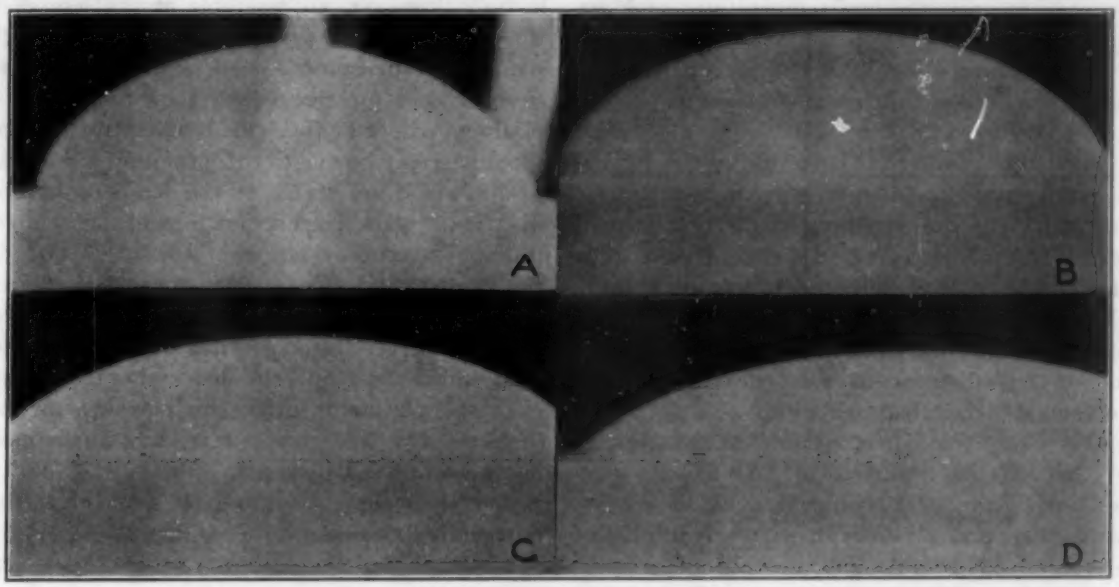

FIG. 6.—Sodium silicate (42% Na_2O) on platinum (1000°C) after entrance of oxygen.

This has been of especial interest to the earlier proponents of a so-called "Beilby" layer. More recent investigations have been made on oxide coatings existing on metals such as copper[15] and iron.[16] As to the influence that the amorphous layer would have on the liquid-solid or liquid-gas interfacial energy one may say that, within

[14] A. W. Hull and E. E. Burger, "Glass-to-Metal Seals," *Physics*, **5** [12] 384–405 (1934); *Ceram. Abs.*, **14** [6] 136 (1935).

[15] (*a*) M. Miwa, "Nature of Polished Layers of Metals," *Sci. Repts. Tôhoku Imp. Univ.*, Series 1, **24** [2] 222–39 (1935); *Ceram. Abs.*, **15** [1] 1 (1936).

(*b*) G. D. Preston and L. L. Bircumshaw, "Studies on Oxidation of Metals: II, Copper, Brass, Aluminum Bronze, Magnesium, and Some Magnesium Alloys," *Phil. Mag.*, [7] **20**, 706–20 (1935); "Effect of Heat Treatment on Structure of Gold and Silver Leaf," [7] **21**, 713–27 (1936).

[16] H. R. Nelson, "Primary Oxide Film on Iron," *Jour. Chem. Phys.*, **5** [4] 252–59 (1937); *Ceram. Abs.*, **16** [8] 237 (1937).

the time necessary for the glasses to come to equilibrium in the experiments studied here, the surface would have undergone enough recrystallization to make it like the surface of unpolished metal treated in a similar manner. Tammann[17] has shown that recrystallization in metals, in general, becomes appreciable at temperatures which are approximately one-half of the melting point. Visual examination of the piece of polished gold after its removal from the furnace on completion of an experiment shows conclusively that the original mirrorlike polish has been substituted by a different type of surface. Direct evidence has been obtained by Preston and Bircumshaw[15(b)] to show that, in the case of gold leaf recrystallization, processes go on at comparatively low temperatures and are much enhanced by the presence of gases such as oxygen. These same studies, however, have led to the conclusion that no oxide layer is present on a gold surface.

Bartell and Miller[13(b)] have studied the wetting of platinum and gold surfaces by water. In one case, they cite evidence produced by Ouillet and Rideal[18] on photoelectric studies on gold to show that absorbed oxygen is present on the surface, although Bartell and Miller conclude, as a result of their own work, that any change in the behavior of gold surface on heat treatment is due to changes other than oxidation.

(*b*) *Gold Surface Free of Oxide:* The facts that (1) the extent of wetting of a gold surface by sodium silicate is not influenced by an oxygen atmosphere and (2) no evidence seems to exist of a stable oxide of gold indicate that the wetting of gold by sodium silicate is controlled simply by the nature of the glass and the metallic gold surface as such.

(*c*) *Surface Studies on Platinum:* In the case of platinum, there is not as abundant evidence to show the nature of the behavior of its surface in the presence of various gases. Hull and Burger[14] state that platinum is known to possess a very stable oxide layer. An inspection of the data presented here shows, however, a striking similarity of the behavior of the sodium-silicate glass on the gold and platinum surfaces in the presence of the atmospheres of nitrogen and vacuum. The marked difference in their behavior as soon as oxygen is allowed to enter must be explained on the basis of the change in interfacial energy due to the formation of some surface oxide or silicate which, however, can be decomposed by reduction of the partial pressure of oxygen gas.

Data are given by Wöhler and Frey,[19] who describe the behavior of the oxides of platinum when subjected to decomposition by heat. These data are obtained on the oxides in bulk, and the results can not be applied with any certainty to give the decomposition temperature of oxides constituting the surface layer. The platinum oxides in bulk, however, are unstable at the temperatures investigated here. Two other alternatives remain. A platinum silicate may form, whose oxygen-vapor pressure is less than the ordinary platinum oxides at the same temperature, or the spreading may be due to the formation of iridium oxides which are stable at the temperatures in question.[20] The presence of a small amount of iridium is certainly not improbable. Whatever the compound formed, which so materially reduces the interfacial tension, its velocity of formation is very rapid as witnessed by the speed with which the fluid lithium metaborate spread over the platinum surface on entrance of the oxygen. The slow rate of spreading in the case of the sodium silicate is a measure of its viscosity rather than the rate at which new interfacial energies are established.

In the case of the platinum surface, it is concluded that wetting takes place on a platinum surface of a similar kind to that encountered in gold and that further wetting may be promoted by the formation of an oxide layer. This latter reaction may be reversible and depends on the pressure of the oxygen. The wetting can then take place both with and without the presence of an oxide layer. The amount necessary to cover a given flat area by spreading would, of course, be much different owing to the establishment of different angles of contact. In any case, it is interesting to contrast the behavior of a

[17] (*a*) G. Tammann, "Temperature of Beginning of Inner Diffusion in Crystals," *Z. anorg. allgem. Chem.*, **157**, 321 (1926).
(*b*) G. Tammann and A. Zworykin, "Determination of Agglomeration Temperatures," *ibid.*, **176**, 46–48 (1928).

[18] C. Ouillet and E. K. Rideal, "Investigation of Adsorbed Films by Means of a Photoelectric Counter," *Jour. Chem. Phys.*, **3**, 150–58 (1935).

[19] L. Wöhler and W. Frey, "Solid Solutions from Dissociation of Oxides of Platinum," *Z. Elektrochem.*, **15**, 129–42 (1909).

[20] L. Wöhler and W. Witzman, "Formation of Solid Solutions during Dissociation of Iridium Oxide," *ibid.*, **14**, 97–107 (1908).

sodium-silicate melt on the noble metals of gold and platinum with behavior on a carbon surface. The work of adhesion is 481, 431, and 68, respectively, based on data *in vacuo*. The datum for carbon is taken from Part I of this paper.

The use of graphite blocks or tools in shaping articles by the glassblower is well known, as also the use of carburized or graphitized iron molds in the factory. Both of these uses depend to a large degree on the poor wetting characteristics of graphite by glass.

VIII. Summary

(1) The equilibrium contact angles of molten sodium silicate at 1000°C on the metals gold and platinum *in vacuo* and in nitrogen and oxygen atmospheres and of lithium metaborate on platinum in nitrogen and *in vacuo* were determined and photographic records were made.

(2) The rate of spreading of the liquids is largely determined by their fluidity (*i.e.*, inversely as the viscosity).

(3) The values of the work of adhesion were calculated from the surface-tension data of the melt and the contact angles.

(4) Gold and platinum are wet in the absence of oxygen; in the case of platinum, however, a marked increase of wetting occurs in the presence of oxygen. It is believed that a platinum oxide (or possibly an iridium oxide) film is responsible. The platinum contained small amounts of iridium.

(5) Molten sodium silicate and lithium metaborate show distinctly less adhesion on a surface of electrode graphite than they do on oxygen-free gold or platinum.

(6) Some applications of these facts to the sealing of wires into glass and to the use of graphite or graphitized surfaces in shaping hot glass are briefly mentioned.

Acknowledgments

The authors wish to acknowledge the coöperation of Allan Martin in the photography of the sessile drops. The discussions with F. J. Williams, G. J. Bair, Jack Sherman, H. M. Krutter, E. F. Williams, and Paul L. Smith were of material assistance in solving special problems that arose. Mr. Sheeder and Mr. Marshall of the machine shop of the School of Mineral Industries gave expert assistance in building the metal portions of the apparatus.

Department of Ceramics
Pennsylvania State College
State College, Pennsylvania

COMMENT* ON BARRETT AND TAYLOR'S "METHOD FOR STUDYING FLOW CHARACTERISTICS OF GLASSES AND SLAGS AT ELEVATED TEMPERATURES"[1]

By J. H. D. Heine

The authors[1] describe an interesting extension of their method to the study of the interfacial tension between molten glass and some solid body. The knowledge of this tension may be helpful in solving several glazing and enameling problems.

In interpreting the results of the experiment, however, the authors make a mistake which the writer believes to be of sufficient fundamental importance to justify a rectification. Their suggestion that the liquid will flow out over the solid as soon as the angle of contact becomes greater than 90° is wrong.

The triple point of contact, P, in Fig. 1 (more exactly the line of contact of which P is the intersection with the plane of design) can move over the solid surface under the influence of the three interfacial tensions, K_{LG}, K_{LS}, *and* K_{SG}. These forces are in equilibrium when

$$K_{SL} = K_{LG}\cos\phi + K_{SG}$$

$$\cos\phi = \frac{K_{SL} - K_{SG}}{K_{LG}}.$$

Now there are several cases to be distinguished.

(1) $\frac{K_{SL} - K_{SG}}{K_{LG}}$ is equal to or greater than 1. This case can never occur; the solid-liquid interface would decrease to zero and the drop, if small enough at least, would lie as a perfect, unflattened sphere on the solid surface.

(2) $\frac{K_{SL} - K_{SG}}{K_{LG}}$ is between 1 and 0.

ϕ is between 0 and 90°, and the drop will take the shape of Fig. 1.

(3) $\frac{K_{SL} - K_{SG}}{K_{LG}}$ is between 0 and -1; therefore ϕ is between 90° and 180°.

According to Barrett and Taylor, the drop will now flow out over the surface. This is not quite true; the drop will take a well-defined shape (see

* Received December 27, 1937.

[1] E. P. Barrett and J. A. Taylor, *Jour. Amer. Ceram. Soc.*, **19** [2] 39–44 (1936).

Fig. 2) that represents a state of perfect equilibrium. A well-known example of this case is a drop of water on a somewhat dirty glass surface.

(4) $\frac{K_{SL} - K_{SG}}{K_{LG}}$ is equal to or smaller than -1. K_{SG} equals or exceeds the sum of K_{SL} and K_{LG}; ϕ becomes 180° or even imaginary, and equilibrium is impossible. Only now the drop will completely flow out and wet the surface.

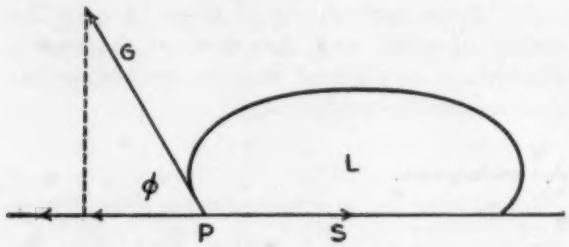

FIG. 1.

It may be concluded from the foregoing data that the graph in Fig. 7 of Barrett and Taylor's article does not indicate the temperature at which the flowing out of the drop occurs. The observations should have been continued until the contact angle becomes, or at least approximates, 180°. The deflecting of the upper ends of the

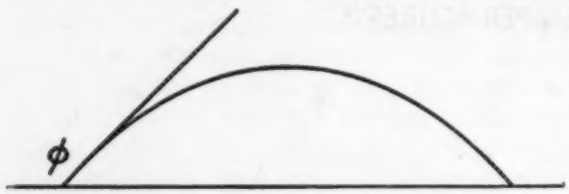

FIG. 2.

curves to the right raises a surmise that the corresponding temperature will be less sharply defined than that at which the contact angle becomes 90°. But, for the practical purposes for which the method was invented, it will do all the same.

BURGEM. THOMASSENSTRAAT 2
HEER-MAASTRICHT
THE NETHERLANDS

Reply by J. A. Taylor

I am in agreement with Heine on his comments and am glad that he agrees with our general idea of the wetting for practical purposes. It is possible to have a drop in equilibrium with a contact angle greater than 90° and this was not made clear in our paper. It was, however, an oversight on our part. It is impractical to measure the temperature at which the 180° contact angle is reached, so for all practical purposes our method as described is quite good as an indication of wetting or at least a tendency to wet. From the slope of the curve, contact angle *versus* temperature, it is possible to tell how great this tendency is at any time during the experiment. On page 44 of the 1936 issue,[1] *we should have said* "tends to wet and tends to flow out," but in some cases this tendency may cease. For instance, curve 1 seems to be approaching the equilibrium angle at something over 140°.

MINERAL INDUSTRIES EXPERIMENT STATION
PENNSYLVANIA STATE COLLEGE
STATE COLLEGE, PENNSYLVANIA

Reply by E. P. Barrett[3]

Heine's summary of the theoretical considerations involved is admirably clear and concise as well as irreproachably correct. On rereading the statement made at the top of page 44, column 1, of our paper,[1] I observe that we have fallen into the not uncommon error of making a statement based on an assumption without stating the assumption.

The assumption involves the question of what is meant by the "wetting" of a solid by a liquid. An adequate discussion leading up to a theoretically unassailable definition of "wetting" would be rather lengthy and ought, in fact, to be written by a mathematical physicist rather than by a physical chemist. Consequently I shall not attempt such a discussion but simply say that, in selecting a contact angle of 90° as the criterion of the temperature at which wetting begins, we were following what we believed to be a rather widely accepted convention. For example, it is customary to regard the convex meniscus of mercury in a vertical, clean glass tube as indicating that the mercury does not wet the glass. On the other hand, the concave meniscus of water under similar circumstances is customarily considered to indicate wetting.

Strictly speaking, there is every justification for regarding a contact angle of 180° as the criterion of perfect wetting because an angle of 180° indicates that the liquid-solid interfacial tension is

[2] Received January 20, 1938.

[3] Received February 1, 1938.

zero; it is clear, however, that the angle of 180° is not a unique thing but merely a condition which is approached more and more closely as interfacial tension grows smaller and smaller. This is merely another way of saying that the wetting of a solid by a liquid is not a thing which either does or does not occur when the liquid and solid are placed in contact. It is a phenomenon which, under varying conditions, may be expressed (in theory at least) by means of measurable quantities that are infinitesimals in the mathematical sense, *i.e.*, they are variables whose limit is zero.

Not to labor the point further, we may say that the particular value of the contact angle at which wetting is said to begin may be arbitrarily chosen according to the use which is to be made of the measurements. It was our experience, with the typical coal-ash slags with which we were working, that whenever the slag and metal were heated in contact to a temperature such that the contact angle was 90° then, upon cooling, the contracting slag almost invariably adhered so strongly to the base metal as to tear a thin layer of it away from the main body of the metal. On the other hand, if heating were discontinued before the contact angle reached 90°, the slag did not adhere to the metal.

Consequently, in the study of the slagging of grate bars by coal-ash slags, we regarded 90° as the critical contact angle. On the other hand, if one were interested in securing good adhesion instead of preventing adhesion, he might select a larger angle as his criterion.

The foregoing remarks indicate the thought behind the statement (p. 44, line 5) "the liquid wets the solid . . . . ." The additional statement ". . . . . and flows out over it," requires limitation. We did not mean to imply that the liquid would flow out into a thin film as soon as the contact angle exceeded 90° but, as written, our statement is susceptible of that interpretation. It is quite true, as Heine points out, that, at temperatures above that corresponding to a 90° contact angle, an equilibrium between gravitational and surface forces can exist, which equilibrium limits the area over which the slag flows. We observed, however, that, when the billets were heated at the uniform rate of 15°F per minute, the rate at which the slag flowed out over the base always increased quite rapidly once a contact angle of 90° was exceeded. This is probably due to the fact that, by the time the contact angle reached 90°, the viscosity and surface tension of the slags with which we worked had fallen to such low values that they could no longer retard the flow of the billet under gravity. It must be remembered that we never observed our billets under equilibrium conditions and that the angles measured at particular times corresponded to equilibrium values at lower temperatures than those against which the observed contact angles were plotted. This was a matter of expediency to permit rapid measurement and it is probable that, if we had held the furnace temperature constant as soon as the contact angle became 90°, we should have found that the equilibrium angle corresponding to that temperature was anywhere from 30° to 60° greater than 90°. To obtain true equilibrium values, to which Heine's remarks would apply, it would be necessary to raise the furnace temperature in steps, waiting at each successive temperature until the billet had assumed its equilibrium shape. This would be a practical procedure as long as the base metal was not susceptible to oxidation or if a strongly reducing atmosphere were maintained in the furnace, but in our measurements, where iron was used in an atmosphere of combustion gases, the more protracted the measurement the heavier becomes the layer of ferrous oxide on the metal surface. Consequently, to minimize the effect of the changing nature of the metal surface upon the results obtained, we resorted to the technique described in the paper.

I am grateful to Heine for clarifying the theoretical basis of the method and for calling attention to possible misinterpretations of the phraseology, and I wish to thank him for his interest in the paper.

MELLON INSTITUTE
PITTSBURGH, PENNSYLVANIA

ELECTRICALLY FUSED MAGNESIA*

By Harold E. White

Abstract

Electrically fused magnesia has gradually won a place in the special refractories group, owing to its physical superiority over the ordinary grades of dead-burned magnesite. The history of its development dates from the world-war period, when considerable interest was aroused in the sources of supply of magnesite in this country. The economic advantages depend largely on the European situation and the prevailing price for the fused material, but the practical advantages of using a totally shrunk, well-crystallized material are obvious. The crystalline material obtained from various grades of raw material differs somewhat in its physical characteristics, and there is a decided difference in the physical properties between dead-burned magnesite and electrically fused magnesia.

I. Introduction

(1) Historical

Electrically fused magnesia was first investigated when supplies of European magnesite were not easily available to this country and potential reserves of magnesia ore, suitable as a refractory only if fused, were found in the western states. It is necessary, however, to turn to the history of magnesite refractories prior to 1914 to learn the reason for the interest in the electrical fusion process.[1]

As early as 1868, Caron[2] made experiments in France to determine the practicability of adopting magnesia for crucibles and refractory brick and for lining reverberatory steel-melting furnaces.

McDowell,[3] in a review of magnesite refractories, discusses early magnesia crucibles.

In the calcination of magnesite, the crystalline or the dense variety, the product first resulting from the dissociation of $MgCO_3$ consists of very fine-grained amorphous magnesia with a specific gravity of about 3.2 (Donald[4] gives 3.01). This was called α-magnesia by Mellor.[5] If heated at a sufficiently high temperature, this is gradually transformed into the mineral periclase, Mellor's β-magnesia, the specific gravity of which is 3.674. Caustic burned magnesia is composed essentially of amorphous magnesia, while the dead-burned material is largely periclase. The theoretical volume shrinkage accompanying the transformation is 13%. The total shrinkage is actually greater than this because of crystal growth and change in porosity.

Some interesting notes on magnesia are given by Searle.[6]

Insufficiently calcined magnesia may always be recognized by its low specific gravity and by its shrinkage on reheating to 1580°C (cone 26). Raw magnesite has a specific gravity of about 3.0; this is increased from 3.38 to 3.58 on heating in a coal- or gas-fired kiln, and to 3.65 on fusing the material in an electric furnace. The specific gravity of pure periclase, the ideal product, is 3.60 to 3.65.

In an article by Litinsky,[7] the statement is made that magnesia is melted in an electric furnace to produce material resistant to thermal shock and that electrically melted magnesia is used commercially in Germany and England for lining high frequency furnaces.

Of historical interest is a quotation from an article by Ferguson.[8]

The sintering of chemically pure magnesia has been generally regarded as difficult, if not impossible, and the refractory articles referred to are, in fact, found to contain about 2% forsterite ($2MgO \cdot SiO_2$) together with about 1% of other impurities (estimated roughly under the microscope), which act as a bond.

Ferguson used pure calcined magnesia as an insulator in a special electric furnace and, upon dismantling after some high temperature work ranging from 1600° to 1720°C, he found the magnesia in a dense cake surrounding the resistor. H. E. Merwin examined this cake and found periclase with less than $^1/_2$ of 1% forsterite and no

---

* Presented at the Thirty-Ninth Annual Meeting, American Ceramic Society, New York, N. Y., March 24, 1937 (Refractories Division).

[1] The Bibliography of Magnesite Refractories published by the Society in April, 1924, contains many references.

[2] Caron, *Compt. rend.*, **66**, 839 (1868).

[3] J. S. McDowell and R. M. Howe, "Magnesite Refractories," *Jour. Amer. Ceram. Soc.*, **3** [3] 185–246 (1920); p. 211.

[4] W. Donald, "Magnesite and Magnesite Brick," *Trans. Ceram. Soc.* [Eng.], **17**, 486–561 (1917–1918).

[5] J. W. Mellor, "Spalling of Magnesite Brick," *ibid.*, **16**, 85 (1916–1917).

[6] A. B. Searle, Refractory Materials, Their Manufacture and Use, p. 188. Charles Griffin & Co., Ltd., London, 2d ed., 1924.

[7] L. Litinsky, "Development of Refractories Containing Magnesite," *Ber. deut. keram. Ges.*, **16** [11] 565–96 (1935); *Ceram. Abs.*, **19** [9] 276 (1936).

[8] J. B. Ferguson, "Note on Sintering of Magnesia," *Jour. Amer. Ceram. Soc.*, **1**, 439 (1918).

binding material. The crystals of periclase were interwoven to some extent.

Rankin and Merwin[9] claim that no indications of a second form (of magnesia) have so far been observed.

In silicate melts, magnesia crystals are not faceted according to Andersen,[10] but with CaO and Al_2O_3 present, sharply bounded and skeletal octahedrons, sometimes modified by the cube, were frequently seen.

Kanolt[11] places the melting point of magnesia at 2800°C. Inquiry through G. W. Morey of the Geophysical Laboratory indicates that this is the most recent reliable data available.

Singer[12] gives a fusion temperature of 2800°C and a specific gravity of 3.6 (this is probably a reference to Kanolt).

According to McDowell and Howe,[3] Mott* gave the boiling point of MgO as 3600°C.

Ferguson and Merwin[13] further state that only one crystalline form is known, which is isometric, with perfect cleavage and a refractive index of about 1.737.

Slight differences in refractive index indicate solid solutions under some conditions. Mallard[14] found 1.7364 for 96% MgO, density 3.50 sodium light, lithium 1.7307, and thallium 1.7413; Wright[15] found 1.734 ± 0.002; Sommerfeldt[16] found 1.7350 (yellow), 1.7298 (red), and 1.7460 (blue). Ferguson and Merwin[13] found 1.7375 for some fused magnesia of optical quality. The dispersion of this sample was $C = 1.7335$, $F = 1.7475$.

Magnesia crystals have been observed in melts as rounded grains, sharp octahedrons or cubocta-

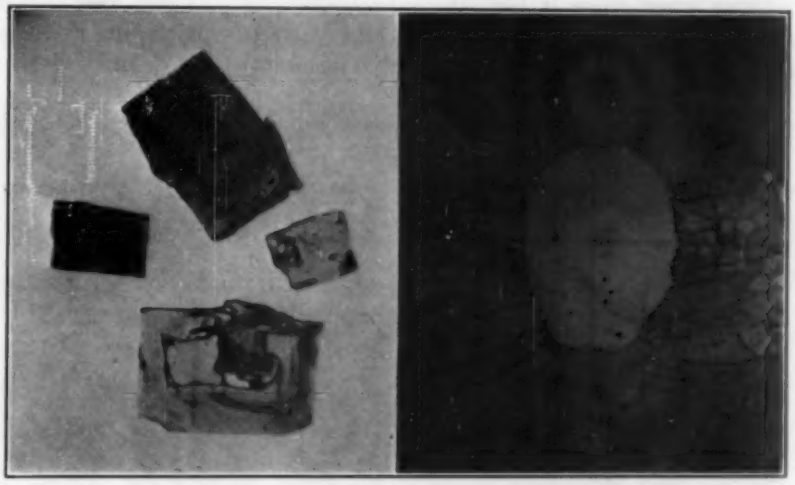

FIG. 1 (*left*).—Magnesia (periclase) cubes, 10×.
FIG. 2 (*right*).—Cross-section of stalactite, 10×.

hedrons, and skeletal octahedrons.

Rees and Chesters,[17] working with magnesite and zircon, make the following statement:

> When magnesite is dead-burned, considerable shrinkage occurs. If, after dead-burning, the magnesia is raised to a temperature as high or higher than that at which it was dead-burned, this shrinkage continues, apparently due to crystallization of the magnesia in a more dense form. In an ordinary magnesite brick, the periclase grains are very irregular in external form, whereas in electrically fused magnesia an amazingly regular cubic structure is obtained. In one sample of magnesia examined, an intermediate type of crystal with some curved and some straight faces was observed.
>
> This shrinkage of magnesia is a source of difficulty, since when it occurs it often results in the cracking of the article.
>
> Because magnesia is a cubic mineral, complete darkness would be expected under crossed-nicols. Actually this is not obtained with Radenthein magnesite, probably due to impurities in solid solution or to a doubly refracting matrix surrounding the grains.

II. Raw Materials

A good survey of the sources of magnesite, particularly in the western states, is given by McDowell and Howe.[3]

[9] G. A. Rankin and H. E. Merwin, "Ternary System CaO–Al_2O_3–MgO," *Jour. Amer. Chem. Soc.*, **38**, 570 (1916).

[10] Olaf Andersen, "System Anorthite–Forsterite–Silica," *Amer. Jour. Sci.*, [4] **39**, 407–54 (1915); p. 421.

[11] C. W. Kanolt, "Melting Points of Some Refractory Oxides," *Jour. Wash. Acad. Sci.*, **3**, 315 (1913).

[12] Felix Singer, "Physical Properties of Ceramic Bodies," *Z. Electrochem.*, **32**, 382–85 (1926); *Ceram. Abs.*, **6** [2] 76 (1927).

* W. R. Mott, 1918 meeting, American Electrochemical Society.

[13] J. B. Ferguson and H. E. Merwin, "Ternary System CaO–MgO–SiO_2," *Amer. Jour. Sci.*, [4] **48**, 284 (1919).

[14] F. E. Mallard, "Note on Artificial Periclase," *Bull. soc. franç. minéral.*, **16**, 18–19 (1893); abs. in *Chem. Zentr.*, **5** [Part 2] 1024 (1893).

[15] E. S. Shepherd, G. A. Rankin, and F. E. Wright, "Binary Systems of Alumina with Silica, Lime, and Magnesia," *Amer. Jour. Sci.*, [4] **28**, 325 (1909).

[16] E. Sommerfeldt, "Note on Periclase," *Centr. Mineral. Geol.*, 212–14 (1907); *Chem. Abs.*, **1** [Part 2] 1529 (1907).

[17] W. J. Rees and J. H. Chesters, "Preliminary Investigation of the Magnesia-Zircon Series," *Trans. Ceram. Soc* [Eng.], **29**, 309–16 (1930).

Magnesite, as now used for electrical fusion, is found in workable quantities in California and Washington. It is also found in South America, Europe, Asia, and Africa.

It is seldom found in quantity in a pure state, and it usually contains iron, alumina, silica, and lime.

Often when silica is low, the lime content is high, as in California magnesite. The reverse is also true, but silica is less objectionable as an impurity than lime. Most of the high-purity ore must be hand-picked.

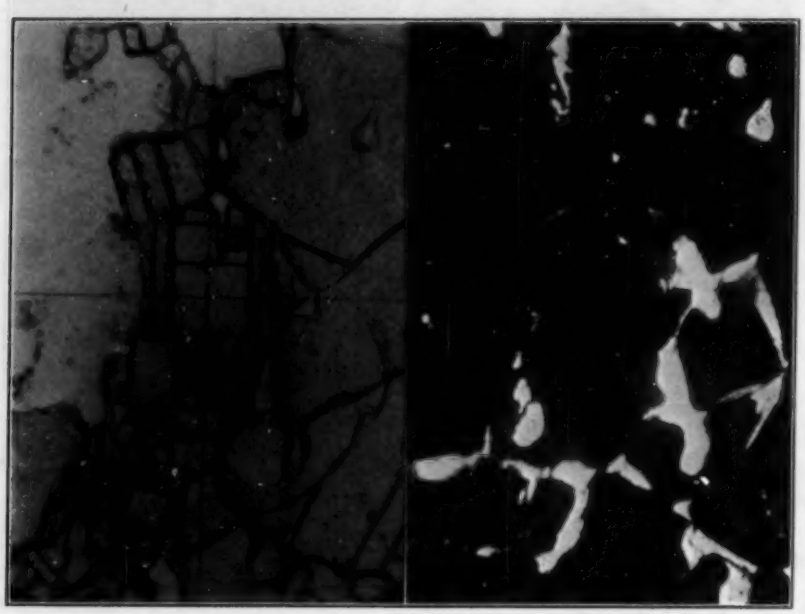

FIG. 3.—Longitudinal section of stalactite; *eft*, plane; *right*, crossed-nicols, 60×.

Some high-grade material comes from India and from Jugoslavia. The analyses in Table I are typical of this material shipped into the United States as caustic calcine.

TABLE I

	Source						
	India	Jugoslavia					
		(1)	(2)	(3)	(4)	(5)	(6)
SiO_2	2.90	0.77	1.14	1.86	0.94	1.06	1.18
Fe_2O_3	0.10	0.04	0.02	0.037	0.03	0.01	0.027
Al_2O_3	0.21	0.04	0.02	0.016	0.02	0.05	0.022
CaO	1.20	1.13	1.15	1.10	1.14	0.80	1.18
Ignition loss	5.50	3.75					

For further analyses see Table II.

III. Physical Chemistry of Magnesia

In the work of Fisk and McCaughey[18] on magnesium oxide in the system magnesia–alumina–iron oxide, electrically fused magnesia of 96% MgO content was used, which makes some of the results of particular interest here.

They state that magnesia in the form of periclase has a low solubility in open-hearth slags and possesses the property of absorbing several times its own weight of iron oxide without seriously impairing its use as a refractory. These properties are distinctive for periclase and are possessed by no other known refractory.

Further evidence of the solution of iron oxide in the periclase was shown by the high index of refraction (greater than 1.80); the index of refraction of iron-free periclase is 1.736.

Moreover, MgO was found to have the ability to take up four times its own weight of iron oxide to form a compound, magnesioferrite (MgO 20%, Fe_2O_3 80%), which is one of a group of minerals known as spinel.

Two principal phases were found, (1) solid solution of iron oxide in periclase and (2) dustlike inclusions with imbedded periclase, practically colorless, and with an index of refraction of 1.74.

The effect of slow cooling on solid solution of Fe_2O_3 in the periclase was to precipitate by selection most of the iron oxide in a form which X-ray analysis has proved to be magnesioferrite.

These experiments showed that at high temperatures iron oxide is taken up in solid solution by magnesium oxide and, by decreasing the temperature, is later thrown out of solid solution or precipitated by selection from the solid solution as magnesioferrite.

It was concluded that the solid solubility of iron oxide in periclase increases considerably with the temperature, and at room temperature it is only 3%.

Magnesium-iron oxide test pieces, which con-

[18] H. G. Fisk and W. J. McCaughey, "Equilibrium Studies in Systems Containing Magnesium Oxide, Iron Oxide, and Magnesium Aluminate," *Ohio State Univ. Eng. Expt. Sta. Bull.*, No. 70, pp. 1–44 (1932); *Ceram Abs.*, **12** [3] 128 (1933).

tained as much as 70% iron oxide, upon quenching from high temperature, showed by X-ray analysis the presence of periclase as the only crystal phase.

It is stated in the Fisk and McCaughey work[18] that the presence of MgO, in large quantities at higher temperatures, seems to favor the formation of ferrous iron. The writer doubts this point, inasmuch as later work shows that the furnace atmosphere plays an important part.

Fisk and McCaughey[18] conclude as follows:

(1) Iron oxide passes into solid solution in periclase to a considerable degree at high temperatures, probably in the form of $MgO \cdot Fe_2O_3$, which may have Fe_2O_3 associated with it in the solid solution, because $MgO \cdot Fe_2O_3$ and Fe_3O_4 are isomorphous. The degree and character of this solid solution depends upon the temperature and the amount of iron oxide present.

(2) Iron oxide which has been in solid solution in periclase at high temperatures is thrown out of solid solution or selectively precipitated by slow cooling almost immediately in the form of magnesioferrite. In case the periclase containing iron oxide in solid solution is cooled rapidly but not quenched, the precipitated magnesioferrite is so finely and uniformly distributed that the product appears to be a homogeneous phase even under the highest power of the microscope, but the presence of the two crystal phases can be shown by means of X-rays.

(3) Periclase has the ability of taking into solid solution large amounts of ferrous oxide as well as ferric oxide, and the solid solutions formed at high temperatures show by analysis both ferrous and ferric oxides in variable amounts depending upon the composition and temperature of the system.

(4) In mixtures of periclase and iron oxide (containing less than 10% of iron oxide) which were quenched from a high temperature, ferrous oxide is in excess of the amount required to form magnetite. These cones were homogeneous and dark green. The close similarity in molecular volume, the space lattice, and the dimension of the unit cube of MgO and FeO would indicate that where it is possible to protect the FeO by a large volume of MgO, the former passes into solid solution in MgO. This is in keeping with the observed fact in mineralogy that FeO often replaces MgO in silicates and other compounds.

(5) When large amounts of iron oxide are present in solid solution, magnesium oxide appears to have the effect of lowering the oxygen pressure of ferric oxide to a remarkable degree. That is, it tends to keep iron in the ferric condition well above the dissociation temperature of ferric oxide, even above the melting temperature of magnetite. This fact is in accord with microscopic observations made upon thin sections of basic open-hearth steel slags.

Another interesting study on the physical chemistry of magnesite is that of Taylor and Williams,[19] who make the following statement:

Given sufficient time for complete diffusion, the final product would be either forsterite or enstatite, not both, the one formed being the one with the lower lattice energy.

In dolomitic rocks carrying silica as the only impurity, Harker[20] records that the "first mineral to form, and with a limited supply of silica the only mineral, is the magnesian forsterite." Our observations on magnesite and quartz, when fired at 800°C in the enstatite ratio, do not show enstatite but rather forsterite. Enstatite appears only at 1000°C.

Harker[20] goes on to say that

If the original dolomitic rock contained more silica than would suffice to convert all the magnesia to forsterite, a lime-bearing silicate makes its appearance. This, however, is not wollastonite but the double silicate, diopside, which is then found accompanying or replacing the forsterite.

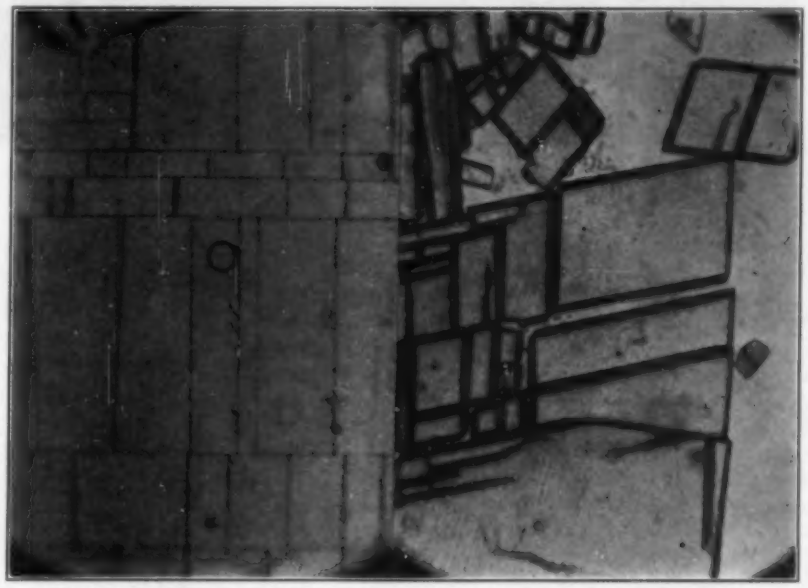

FIG. 4.—Columnar dark colored material; plane polarized light, 60×.

A mixture of dolomite and quartz in proportions, expected to produce diopside at 1000°C, produced diopside, akermanite, and monticellite but no trace of wollastonite.

[19] N. W. Taylor and F. J. Williams, "Reactions between Solids in the System CaO–MgO–SiO_2 in the Temperature Range 600°C and 1200°C," *Bull. Geol. Soc. Amer.*, **46**, 1121–36 (1935); p. 1126; *Ceram. Abs.*, **15** [5] 169 (1936).

[20] Alfred Harker, Metamorphism. Methuen & Co. Ltd., London, 1932.

From the British technical press the following items by Patrick[21] are of interest.

Crystalline magnesia obtained by fusing magnesite of a high degree of purity is highly inert to the chemical action of metals, basic slags, and the usual fluxes at high temperatures. In spite of its high thermal conductivity, it is a poor conductor of electricity. Impurities, particularly silica and ferric oxide, influence most of these properties adversely. The crystalline form is stable at all temperatures below the fusion point. No sudden changes in physical properties occur during heating or cooling.

FIG. 5.—Light colored material; *left*, crossed-nicols gypsum plate; *right*, crossed-nicols, 60×.

In the electrometallurgical industries,[22] a demand exists for a material which, although possessing an exceedingly low electrical conductivity, is yet a good thermal conductor and which, moreover, remains not only inert to the corrosive actions of atmospheric conditions and of hot metals but also physically unchanged during succeeding thermal cycles. Such properties are possessed by pure fused magnesia which is obtained by heating magnesite or the magnesia obtained by the calcination of it in the electric furnace at 3000°C, whereupon practically pure beta magnesia (periclase) is obtained. It is composed of crystals of the cubic system, octahedral in form. This product is superior to the varieties obtained at the lower temperatures and has a much smaller, nearly negligible tendency to hydrate, increased electrical resistance, increased thermal conductivity, increased resistance to chemical attack, and increased hardness.

An older article by Watts[23] gives the following points:

(1) At extremely high temperatures, MgO and carbon react rapidly, and in a closed vessel a solid black product results.

(2) Reaction: $MgO + C = Mg + CO$.

(3) Reaction is reversible and at lower temperature reforms MgO and carbon as an intimate mixture.

(4) Magnesia containing iron oxide in large amounts may be freed from this impurity by heating strongly in an electric furnace of the resistor type.

(5) Magnesia is reduced more rapidly by certain carbides than by pure carbon. The carbides of Fe, Ni, and Cr are particularly active as is silicon carbide.

IV. Experimental Work on Fused Magnesia

Several reactions take place with this interesting material. A solid lump as it comes from the furnace is white or has a greenish tinge. Roasting it in an oxidizing atmosphere changes the state of the iron and the green piece becomes brown. Reducing conditions change it back to the original color (see Fig. 17).

This reaction, which is evidently one of ferrous to ferric iron and back again, takes place even in a large lump with no apparent porosity. Sutton and Fritze* claim increased electrical resistivity due to roasting.

At times some grayish pieces are encountered. These represent carbon inclusions. They can be removed by roasting, although here again some mass action takes place to free carbon from the center of an impervious lump.

With lime content of the caustic of more than 2%, the tendency toward carbon pick-up from electrodes increases. Moreover, a dissociation takes place which is probably from β- to α-di-

[21] W. L. Patrick, "Fused Magnesia in the Nonferrous Industry," *Metal Ind.* [London], **48** [8] 231–32 (1936); *Ceram. Abs.*, **16** [3] 91 (1937).

[22] B. Moore and W. L. Patrick, "Fused Magnesia," *Ind. Chemist*, **11** [127] 318–20 (1935); *Ceram. Abs.*, **15** [10] 302 (1936).

[23] O. P. Watts, "Action of Carbon on Magnesia at High Temperatures," *Trans. Amer. Electrochem. Soc.*, **11**, 279 (1907).

* R. J. Sutton and J. R. Fritze, "Process for Increasing Electrical Resistance of Fused Magnesium Oxide," U. S. Pat., 2,012,897, Aug. 27, 1935.

calcium silicate or some similar reaction, such as the decomposition of the orthosilicate.

Iron oxide does not seem to penetrate the periclase crystal itself, but the surrounding matrix seems to absorb it, at least up to a certain concentration.

Reference to the ternary diagrams, MgO–CaO–SiO_2, MgO–CaO–Al_2O_3, and MgO–Al_2O_3–SiO_2, shows the possibility of formation of compounds with magnesia and impurities, but it does not indicate the possibility of their occurrence in commercial production of a fused material such as this.[24]

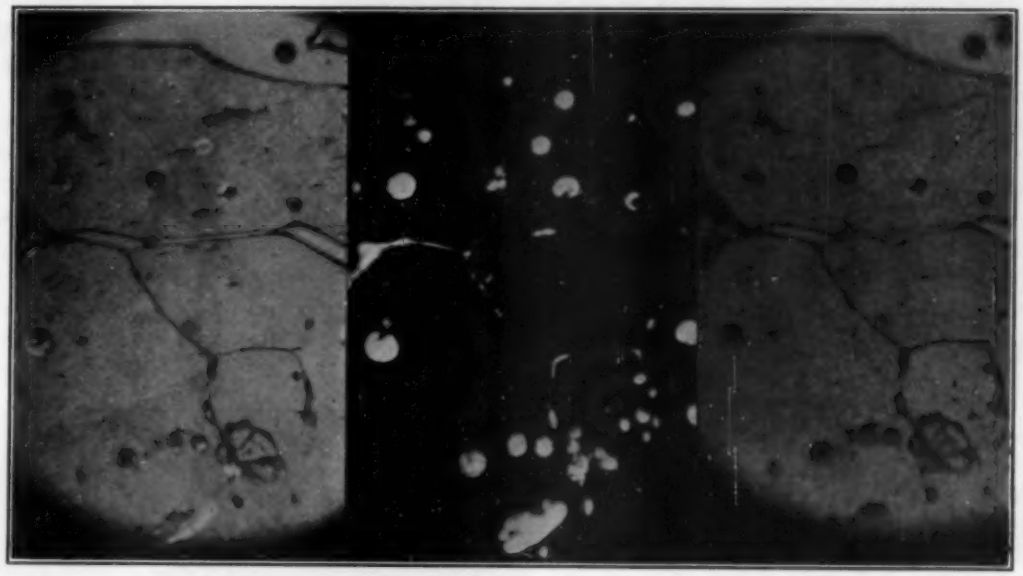

FIG. 6.—Light colored columnar material showing inclusions; *left*, crossed-nicols; gypsum plate; *center* (crossed-nicols); *right*, plane polarized light, 60×.

A glance at the cut sections of Figs. 3, 4, and 5 shows what actually happens. The periclase crystallizes out leaving a liquid rich in impurities, and subsequently the secondary minerals crystallize along the mineral contact planes as may be observed in the sections using crossed-nicols. Fortunately, this is easily brought out with periclase, inasmuch as the major impurity, forsterite, is anisotropic. An interesting phenomenon is observed in the forsterite impurities shown as inclusions in Fig. 6.

With dark-colored material which has absorbed carbon, the carbon inclusions are similar and upon subsequent burning out of the carbon in an oxidizing atmosphere some forsterite is often left in the cavity; the inclusion, therefore, must have been a mixture of forsterite and carbon.

Comparison of Figs. 9 and 10 with Figs. 8 and 11 and 13 shows (1) the different nature of crystallization due to heating and fusion, (2) the diffusion of the impurities in the heated material, (3) the apparent sharp crystallization of the parent material, and (4) the impurities in the product resulting from the fusion.

The history of the raw material before fusion plays an interesting rôle in the character of the product.

Re-fused fines, that is, fine material resulting from fused material crushed and re-fused, as a general rule, result in a sugary structure. This is apparently a mass of fine crystals held together by a bond of different degrees of strength.

Material fused directly from calcined caustic gives clear columnar crystals, well-bonded and very tough.

An intermixture of partially fused material seems to result in a fair proportion of platy material.

V. Petrographic Examination

(1) Columnar Crystals

Columnar crystals are usually clear and cemented together with a glass (see Figs. 1, 2, 3, 4,

[24] Reference to these diagrams may be made to the phase-rule diagrams edited by F. P. Hall and Herbert Insley as follows: MgO–CaO–SiO_2, see *Jour. Amer. Ceram. Soc.*, **16** [10] 520 (1933); MgO–CaO–Al_2O_3, *ibid.*, p. 518; and MgO–Al_2O_3–SiO_2, *ibid.*, p. 526.

and 8). Usually there is little anisotropic material, and the Nd is 1.735 + 0.001.[25] A small amount of forsterite appears to be present, and there is relatively high birefringence.

Upon roasting this material in oxidizing atmosphere, the index of refraction of the isotropic and birefringent material appears to increase, probably due to the fact that iron is absorbed from the glass by the crystals and is in solid solution in the periclase and forsterite.

(2) Platy Crystals

The index of refraction of platy crystals (Fig. 5) is close to 1.735 and quite a little forsterite is present. This type of crystal is not as pure as the columnar crystal.[26]

The pieces break from a large massive structure into small plates. When ground to pass 100-mesh, they break into rectangular plates with a refractive index of less than 1.74. Under the microscope there is little difference between the columnar and the platy crystals. The plates show numerous anisotropic inclusions which are positive and biaxial, indicating forsterite.

(3) Sugary Crystals

The crystals appear to be smaller than in the platy structure. Under the microscope, they are similar, but the crystals are octagonal, whereas the platy and columnar structures tend toward the cubic.

With minus 100-mesh material screened from daily run-of-furnace material (Fig. 12) the following data were obtained:

(1) Isotropic crystals (periclase): refractive index, 1.74.

(2) Anisotropic material: Nm, 1.647; Ng, 1.658–1.65, 1.658–1.669. Optically biaxial positive mineral: large optic angle (forsterite); birefringence relatively high.

(3) Biaxial optically negative mineral: Ng, 1.680; Np, 1.663; birefringence much lower than forsterite, probably monticellite ($CaO \cdot MgO \cdot SiO_2$).

(4) Akermanite, uniaxial optically negative; refractive index, 1.63 with low birefringence.

(5) A sample of fines was then digested in acid, and sufficient clear isotropic crystals of the same optical characteristics as periclase were identified to be sure of the presence of spinel (refractive index below 1.74, above 1.68).

(6) Further digestion of the fines in aqua regia disclosed a glass with a refractive index below 1.40; the composition of this glass is unknown.

Magnesioferrite is consistently reported as being present in magnesite refractories, yet none was found; neither was the so-called beta corundum found although it was carefully sought after.

Inclusions of a biaxial optically positive mineral were observed in the periclase crystals with an oil-immersion lens. These were undoubtedly forsterite (Fig. 6).

It has been observed that where the cubical structure predominates, there are fewer inclusions.

The raw material used contains isotropic clusters; it is semitranslucent and has a refractive index greater than 1.6802 and less than 1.6882.

The anisotropic material has a refractive index of 1.548 to 1.558; it is uniaxial, optically positive with many inclusions, which are undoubtedly quartz.

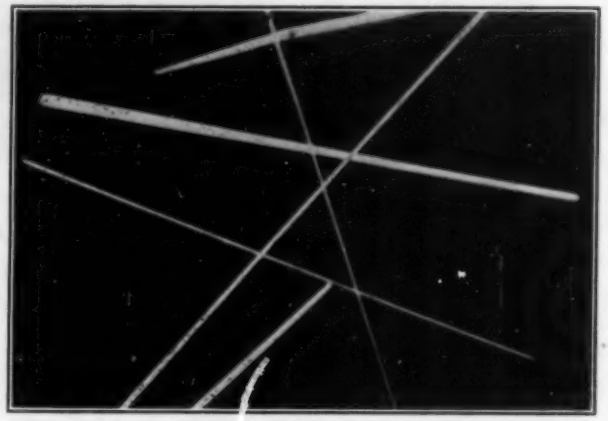

FIG. 7.—Forsterite needles; crossed-nicols needles, 5/8 inch long; 60×.

The isotropic light brown material is more nearly opaque, with a refractive index of 1.680 to 1.672.

Some very fine needles of forsterite were observed on the walls of the larger voids in the melts (Fig. 7).

(4) Discussion of Petrographic Work

Periclase from steel-furnace bottoms has a refractive index as high as 1.80; it usually occurs at 1.75, owing to the iron in solid solution.

It is possible to find in the impurities of ordinary magnesites, monticellite and dicalcium

[25] Herbert Insley, personal communication, Feb. 18, 1937.

[26] H. M. Kraner, personal communication.

silicate or monticellite and forsterite, depending upon the lime-silica ratio, but not all three. Because forsterite predominates in the fused magnesite examined, no dicalcium silicate was found.

It is also possible to find akermanite and spinel. Enstatite or clinoenstatite would not be expected, owing to their instability at the higher temperatures. The other minerals which might possibly be present are wollastonite, pseudowollastonite, and diopside.

In order to study these impurities, the finer screenings from plant runs were examined. It was found that a higher percentage of impurities was present in this material as some of the matrix containing the auxiliary minerals undoubtedly broke down more readily and reported in the fines.

FIG. 8.—Columnar crystalline material; *left*, plane polarized light; *right*, crossed-nicols, 60×.

(5) Indices of Refraction

Indices of refraction for periclase have been given by various investigators. Levy and Lacroix[27] give 1.66 for the natural crystal. This is the only known measurement on the natural mineral and it is apparently too low. Winchell[28] gives 1.730 to 1.739 and in a later work,[29] 1.736±; Larsen[30] gives 1.736.

In a descriptive article on electrically fused magnesia, Konopicky and Kassel[31] make the following statement:

> By increase of silica content, the quantity of calcium magnesium ferrite decreases until at a lime-silica ratio of 1 it vanishes. As long as the calcium ferrite reaction takes place, a portion of the silica

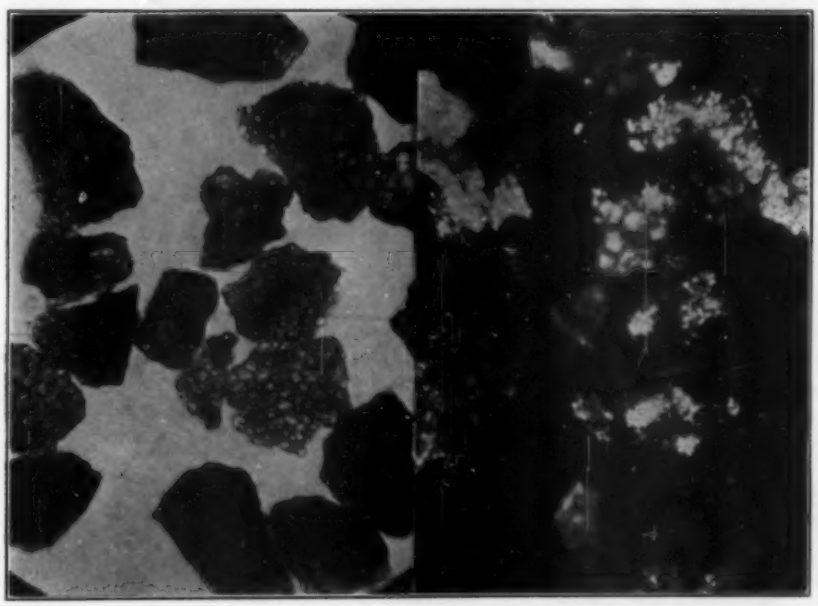

FIG. 9.—California magnesite (calcined) 90% MgO; *left*, plane polarized light; *right*, crossed-nicols, 60 ×.

[27] Levy and Lacroix, *Tabl. Minéral Roches*, 1889.

[28] A. N. Winchell, Elements of Optical Mineralogy, Vol. 2, p. 41. John Wiley & Sons, New York, 2d ed.

[29] *Ibid.*, Vol. 3, p. 120. John Wiley & Sons, 2d ed.

[30] E. S. Larsen and Harry Berman, "Microscopic Determination of Nonopaque Minerals," *U. S. Geol. Surv. Bull.*, No. 848, p. 56 (2d ed., 1934); *Ceram. Abs.*, **13** [7] 196 (1934).

[31] Kamillo Konopicky and Hans Kassel, "Sintered Magnesite: I, Quantitative Investigation of the Compounds Produced," *Ber. deut. keram. Ges.*, **17** [10] 465–83 (1936); *Ceram. Abs.*, **16** [10] 313 (1937).

reports as dicalcium silicate. By disappearance of calcium-magnesium ferrite (excess of silica), monticellite takes the place of dicalcium silicate. Monticellite and calcium ferrite can not exist together.

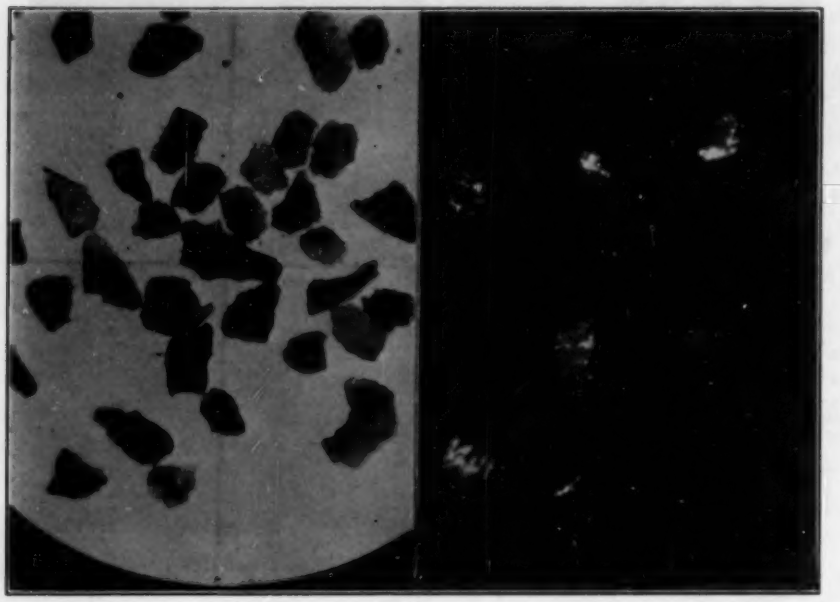

FIG. 10.—California magnesite (calcined) 98% MgO; *left*, plane polarized light; *right*, crossed-nicols, 60×.

The ternary system,[24] $MgO–CaO–SiO_2$, shows the possibility of finding forsterite, monticellite, and akermanite; $MgO–CaO–Al_2O_3$ shows the possibility of the formation of spinel as does $MgO–Al_2O_3–SiO_2$.

Thus the findings of the petrographic examination are substantiated. Seil[32] reports a petrographic examination of domestic dead-burned magnesite as follows:

Primary component	
Periclase	77.28%
Secondary component	
Magnesium ferrite	9.52%
Monticellite	6.28
Forsterite	6.54

(6) Thermal Expansion

The apparatus used is essentially the same as described in the *Journal of the American Ceramic Society*,[33] except that the furnace is more accessible and the samples cut from the solid fused material are held in a fused silica tube (see Fig. 14).

[32] G. E. Seil, personal communication.
[33] American Ceramic Society Standards Report, *Jour. Amer. Ceram. Soc.*, **11** [6] 522–24 (1928).

TABLE II

SPECIFIC GRAVITY AND CHEMICAL DATA

	Specific gravity	Bulk density	MgO	Al_2O_3	SiO_2	CaO	Fe_2O_3	TiO_2
Magnesite*	3.49	2.495	82.04	3.22	5.40	5.03	4.98	0.26
Periclase*	3.37	2.700	85.57	2.27	5.55	4.74	1.53	
Radex†	3.57	3.00	83.54	4.07	3.60	2.60	5.17	0.19
Magnesite‡	3.50	2.54	87.30	0.04	2.70	6.80	3.60	
Magnesite‡	3.48	2.42	88.10	0.04	4.90	4.80	2.00	
Electrically fused MgO (Fig. 11)§			93.93	0.36	2.80	2.06	0.75	
Magnesite‖	3.53	2.34	86.40	6.50	2.70		4.50	
	3.51	2.40	92.10	0.40	5.0	1.70	1.60	
	3.38	2.56	87.9			4.70	2.60	
	3.59	2.54	86.80	0.80	2.60	3.0	6.30	
Magnesite (Fig. 9) (highly calcined)¶	3.536		91.06	0.37	4.20	2.86	2.38	
Electrically fused MgO¶	3.585		94.98	0.35	1.49	1.12	2.06	
			96.21	0.36	1.31	1.82	0.21	(columnar crystals)
	3.573 (platy crystals)							
Caustic calcine (1800°F)¶	3.367		90.00 (Ignition loss 5.50)	0.21	2.90	1.20	0.10	
Domestic dead-burned magnesite**	3.609		84.57	0.09	5.20	2.25	7.60	

* H. E. White, "Electrical Resistivity of Specialized Refractories," *Jour. Amer. Ceram. Soc.*, **15** [11] 598–610 (1932).
† P. P. Budnikoff and B. J. Pines, "Constituents and Properties of 'Radex' Magnesite Brick," *ibid.*, **18** [4] 125–27 (1935).
‡ G. R. Pole and D. G. Moore, "Testing Refractories against Corrosive Action of Electric Furnace Phosphate Slags," *ibid.*, **19** [10] 259–70 (1936).
§ Vitrefrax Co., personal communication.
‖ G. B. Wilkes, "Thermal Conductivity of Magnesite Brick," *Jour. Amer. Ceram. Soc.*, **16** [3] 125–30 (1933).
¶ H. E. White, this paper.
** G. E. Seil, personal communication.

It is necessary to correct for the thermal expansion of the silica,[34] which is as follows:

(°C)	($\times 10^{-6}$)
250	0.476
500	.554
750	.541
750	.535
1000	.534

To check the possibility of nonuniform expansion due to inversion of the tube, a blank rod 3.093 inches long of fused silica was put in the apparatus. From 20° to 1000°C, it showed a possible maximum expansion of 0.00003 inch (0.001%) of 0.01×10^{-6} correction (negative on the thermal expansion). Although the fused silica and brass rods are practically self-compensating, this error will depend somewhat on the room temperature and the circulation of air around the furnace. It is possible to read the Ames dial to 0.0001 on the marked divisions and to estimate to one-fourth of this, so the expansion due to inequalities in the rods or change of state of the silica tube is probably within the limit of error of the apparatus. Results are shown in Table IV.

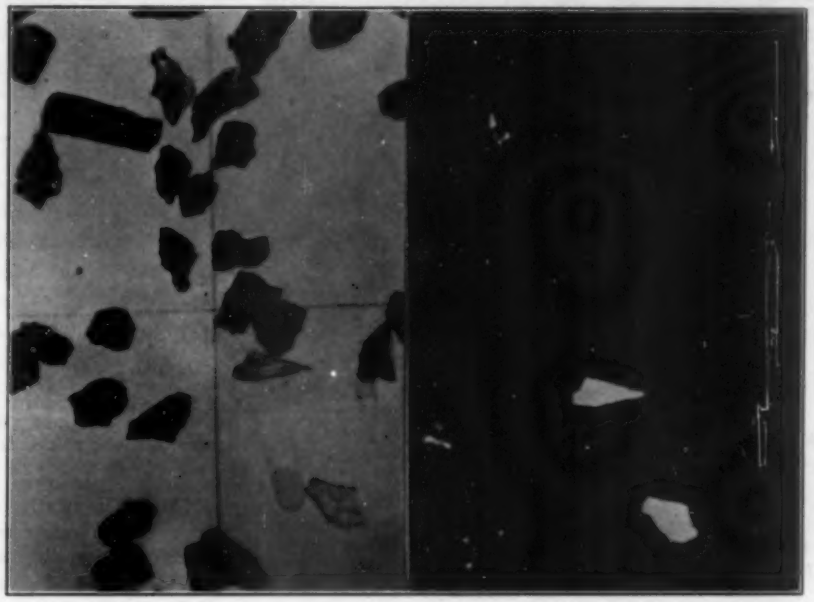

FIG. 11.—Fused magnesia 93% MgO; *left*, plane polarized light; *right*, crossed-nicols, 60×.

Büssem[35] gives the thermal expansion for pure MgO calcined at 1000° as 14.45×10^{-6} as compared to Hirsch,[36] who gives 14.5×10^{-6} for 98% MgO brick, using essentially the same method as the author. His curve does not check his points particularly well, but the usual low temperature curve appears changing to a straight line, an indication of lack of control of heating mechanism.

The logarithmic curves of log t plotted against α are fairly straight (Fig. 16).

Possible variations in constant linear expansion occur at 200° to 300° and again

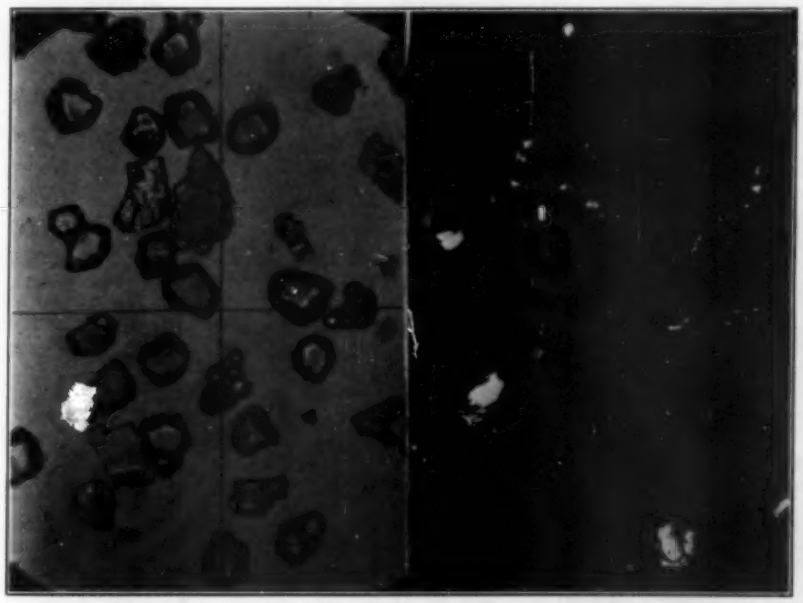

FIG. 12.—Average run fused magnesia 95% MgO; *right*, crossed-nicols; *left*, plane polarized light, 60×.

[34] R. B. Sosman, "The Properties of Silica," p. 402. Chemical Catalog Co., New York (1927); *Ceram. Abs.*, **7** [7] 505 (1928).

[35] Wilhelm Büssem, "Thermal Expansion Measurements of Crystalline Bodies by the X-Ray Method: I," *Ber. deut. keram. Ges.*, **16** [8] 381–92 (p. 387)(1935); *Ceram. Abs.*, **15** [3] 107 (1936).

[36] Hans Hirsch, "Properties of Magnesite Brick," *Tonind.-Ztg.*, **52** [25] 479–83 (p. 482) (1928); *Ceram. Abs.*, **7** [10] 693 (1928).

at 900°. The latter is quite persistent, indicating a possible change of physical state at this point. All determinations were checked twice and questionable readings were rejected and rechecked. Temperature equilibrium was carefully established at each point (50° interval).

TABLE III

THERMAL EXPANSION DATA

Coefficient of linear thermal expansion × 10^{-6}	Temperature range (°C)
13.4*	(20–1355)
13.8*	(20–1800)
13.77†	(20–1000)
13.4‡	(25– 800)
14.45§	
14.50‖	
10.69¶	(15–1100) (Radenthein)
13.4**	(25–800)
13.1††	

* R. A. Heindl, "Thermal Expansion of Refractories to 1800°C," *Bur. Stand. Jour. Research*, **10** [6] 715–35 (1933); R. P. 562; *Ceram. Abs.*, **12** [9] 330 (1933).

† J. B. Austin, "Thermal Expansion of Some Refractory Oxides," *Jour. Amer. Ceram. Soc.*, **14** [11] 795–810 (1931).

‡ G. E. Merritt, "Thermal Expansion of Some Fused Oxides Used as Refractories," *Trans. Amer. Electrochem. Soc.*, **50**, 283 (1926); *Ceram. Abs.*, **6** [1] 27 (1927).

§ W. Büssem, see footnote reference 35.

‖ See Hans Hirsch, footnote reference 36.

¶ See W. J. Rees and J. H. Chesters, footnote reference 17.

** See G. A. Rankin and H. E. Merwin, footnote reference 41.

†† See Felix Singer, footnote reference 12.

(7) Thermal Conductivity

The order of decreasing thermal conductivity of the refractory oxides is undoubtedly SiC, MgO, Al_2O_3, BeO, SiO_2, and ZrO_2.

Sillimanite ($Al_2O_3 \cdot SiO_2$) and mullite ($3Al_2O_3 \cdot 2SiO_2$) come before ZrO_2 and in the same order; zircon ($ZrO_2 \cdot SiO_2$) is probably ahead of silica (SiO_2).

FIG. 13.—Monticellite; crossed-nicols, 280×, 1.67 oil.

In the work of Euken,[37] the following figures of thermal conductivity are given in cal. · cm.$^{-2}$ · cm. · sec.$^{-1}$ · °C^{-1}.

		Thermal conductivity 300°C	700°C	1100°C	
Crystallized	SiC	0.10	0.062	0.044	0.0093 .0239
	MgO	0.048	0.023	.014	.0086 .0080
	Al_2O_3	0.014	0.011	.010	.00498
	SiO_2	0.012	0.009		.00438 .00383
$3Al_2O_3 \cdot 2SiO_2$		0.0089	0.006	.0049	
$Al_2O_3 \cdot SiO_2$				.0086	.00227 .00359
$ZrO_2 \cdot SiO_2$					.00456

* The last column represents work by H. Laube, using a different method. The relative conductivities are the same, but the values differ.

NOTE: The relative conductivities are further borne out by several American investigators working on crystalline refractory materials of approximately the same particle size and without bonds, such as insulating material for electrical strip heaters; and these have been given the writer in personal communications.

Searle[38] gives the following data on thermal conductivity (in g.-cal. · sec.$^{-1}$ · cm.$^{-2}$ · cm. · °C^{-1})

Fine SiC	0.00050
Coarse SiC	0.00051
Fused quartz	0.00039
Fused MgO	0.00047
MgO brick	0.00050
Calcined Greek MgO	0.00045
Calcined Veitsch MgO	0.00034
Pattinson's high calcined MgO	0.00016
Kieselguhr	0.00013

Mellor's reference[39] seems to be from the same source as Searle,[38] but this is not stated. The thermal conductivity at 20° to 100°C is K = 0.00047 cal. · sec.$^{-1}$ · cm.$^{-2}$ · cm. · °C^{-1} for fused MgO powder through a sieve having 600 openings to cm.^{2}, K for fire brick is 0.00028 and for calcined Greek MgO, 0.00045.

For MgO, Singer[12] gives specific gravity 3.6; heat conductivity 0.522 kg. · cal. · M^{-2} ·-

[37] A. Euken, "Thermal Conductivity of Ceramic Refractory Materials. Its Calculation from the Thermal Conductivity of Constituents," *Forschungsheft*, No. 353 (suppl. to *Forsch. Gebiete Ingenieurw.*, **13** [3] (1932)); *Ceram. Abs.*, **11** [11] 576 (1932); **12** [6] 231 (1933).

[38] Encyclopedia of the Ceramic Industries, p. 273. Edited by A. B. Searle, Ernest Benn, Ltd., London, 1930. (Reference is Havard, Refractories and Furnaces, McGraw-Hill Book Co., New York, 1912.)

[39] J. W. Mellor, Inorganic and Theoretical Chemistry, Vol. 5. Longmans, Green & Co., London, 1929.

M·hr.$^{-1}$·°C^{-1}; heat capacity (specific heat) 17° to 100°C = 0.264. International Critical Tables[40] gives $K = 126 \times 10^{-4}$ watt·cm.$^{-2}$·cm.·°C^{-1} at 15°C.

Rankin and Merwin[41] give heat capacity of magnesia with specific gravity 3.6 to 3.7 as 0.232 cal.·g.$^{-1}$ at 50°C.

(8) Electrical Conductivity

Navias[42] gives the order of decreasing electrical conduction of the oxides as (1) ZrO_2, (2) ThO_2, (3) MgO, (4) Al_2O_3, and (5) BeO.

TABLE IV

LINEAR THERMAL EXPANSION DATA (Fig. 15)

	Columnar crystals		Stalactite		Platy crystals	
Temp. t	(%)	(α)	(%)	(α)	(%)	(α)
20	0	0	0	0	0	0
50	0.0207	5.92	0.0217	7.24	0.0187	6.23
100	0.0752	9.40	0.0760	9.51	0.0593	8.35
150	0.1270	9.76	0.1455	10.42	0.0927	9.35
200	0.1832	10.17	0.1892	10.51	0.1555	10.42
250	0.2430	10.58	0.2470	10.76	0.2458	10.68
300	0.3720	11.33	0.3170	11.31	0.3050	10.90
350	0.3808	11.55	0.3808	11.55	0.3810	11.55
400	0.4443	11.65	0.4474	11.78	0.4535	11.92
450	0.5089	11.82	0.5223	12.15	0.5207	12.10
500	0.5865	12.20	0.5862	12.21	0.5822	12.10
550	0.6571	12.40	0.6564	12.39	0.6436	12.12
600	0.7355	12.69	0.7250	12.51	0.7281	12.55
650	0.8071	12.80	0.8035	12.75	0.8010	12.77
700	0.8801	12.95	0.8764	12.89	0.8694	12.78
750	0.9549	13.05	0.9459	12.98	0.9348	12.80
800	1.0249	13.15	1.0261	13.16	1.0010	12.83
850	1.0970	13.21	1.0965	13.20	1.0661	12.85
900	1.1680	13.16	1.1690	13.18	1.1472	13.04
950	1.2530	13.48	1.2610	13.58	1.2284	13.20
1000	1.3334	13.62	1.3314	13.61	1.3034	13.30

Sugarlike masses Log t	(%)		(α)
20–1000°	1.3514		13.78
Platy crystals			
20–1000°	1.3034	run 1 slow	13.30
	1.2784	" 2 "	13.04
	1.2734	" 3 "	12.99
	1.3086	" 4 fast	13.35

(%) = total expansion in percentage of length at 20°C.
(α) = mean linear coefficient of expansion $\times 10^6$ (in.·in.$^{-1}$·°C^{-1}).

According to Goodwin and Mailey,[43] fused magnesia has a higher electrical resistivity than porcelain below 1100°C, but it is lower above that temperature.

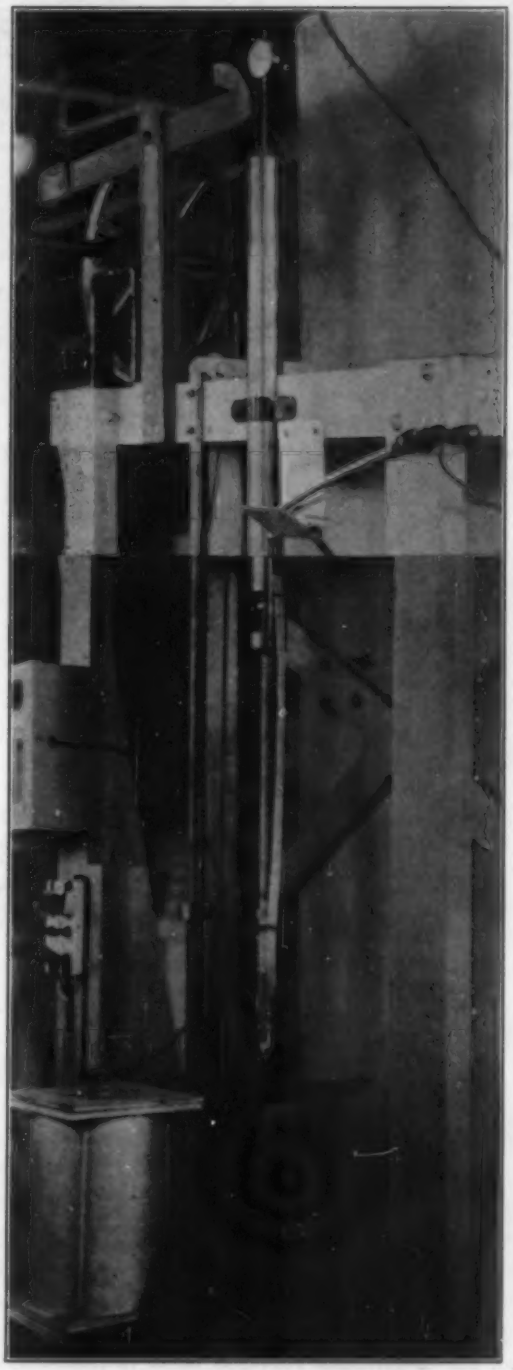

FIG. 14.—Thermal-expansion apparatus.

Northrup[44] gives the following figures for the electrical resistivity of electrically shrunk mag-

[40] International Critical Tables, Vol. 5, p. 217.

[41] G. A. Rankin and H. E. Merwin, "Ternary System MgO–Al_2O_3–SiO_2," *Amer. Jour. Sci.*, [4] **45**, 301–25 (1918).

[42] Louis Navias, "Extrusion of Refractory Oxide Insulators for Vacuum Tubes," *Jour. Amer. Ceram. Soc.*, **15** [4] 234–51 (1932).

[43] Goodwin and Mailey, "Properties of Fused Magnesium Oxide," *Trans. Amer. Electrochem. Soc.*, **9**, 89, (1906).

[44] E. F. Northrup, discussion of paper by O. L. Kowalke and D. S. Grenfell, "Temperature of Reaction between Acheson Graphite and Magnesia," *ibid.*, **27**, 233 (1915).

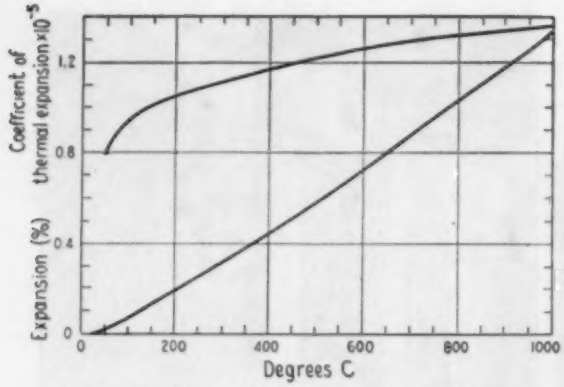

FIG. 15.—Linear thermal expansion curves.

nesia, to which 10% pure $MgCO_3$ has been added for bonding.

Temp. (°C)	Resistivity (ohms/cm.³)
1060	420,000
1100	320,000
1170	62,000
1230	24,000
1352	510
1386	415

This material has the composition given in Table V.

Sommerville[46] worked with pure oxides in a quartz tube under 2 to 4 pounds pressure. According to Hering,[47] he measured actual resistance

FIG. 17.—Showing reversible reaction in fused magnesia caused by furnace atmosphere: (1) original state; (2) oxidized; (3) oxidized piece under reducing conditions.

and not resistivity and introduced errors because of the conductance of the quartz tube. Hering recalculated his results and obtained a curve varying from

TABLE V

	Specific gravity	Bulk density	Pore volume	MgO	SiO_2	Fe_2O_3	CaO	TiO_2
Magnesite*	3.49	2.50	28.51	82.04	5.40	4.98	5.03	0.20
Periclase*	3.37	2.70	19.85	85.57	5.55	1.53	4.74	
Electrically fused MgO†				97.00	1.15	0.25	1.00	

* See H. E. White, star (*) footnote Table II, p. 224.
† See E. F. Northrup, footnote reference 44.

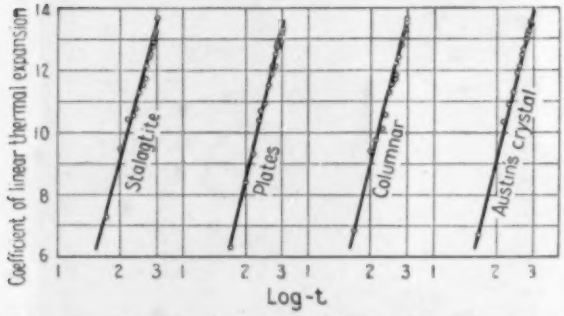

FIG. 16.—Logarithmic curves of linear thermal expansion.

The author[45] has made similar measurements on periclase and magnesite brick, analyses of which are shown in Table V. The resistivity data (Table VI) show a change in slope of the periclase curve at 650°C.

[45] See p. 600 of (*) footnote reference, Table II, p. 224.

4000 to 1500 ohms per cubic centimeter at 1000°C to 200 ohms per cubic centimeter at 1100°C. These readings undoubtedly are too low.

TABLE VI

ELECTRICAL RESISTIVITY OF REFRACTORY BRICK

Temp. (°C)	Periclase		Magnesite	
600	90.70	megohms·cm.⁻³	85.47	megohms·cm.⁻³
700	18.12	"	32.20	"
800	4.36	"	5.15	"
900	1.33	"	1.157	"
1000	71,0,000	ohms·cm.⁻³	193,000	ohms·cm.⁻³
1100	365,000		92,600	
1200	60,600		8,880	
1300	11,500		2,082	

International Critical Tables[48] gives the follow-

[46] Sommerville, "Variation of Electrical Resistance of Oxides with Temperature," *Met. Chem. Eng.*, **10** [7] 422 (1912).
[47] Carl Hering, "Comparisons of Electrical Resistivities at High Temperatures," *ibid.*, **13** [1] 23 (1915).
[48] International Critical Tables, Vol. 6, p. 149.

ing values for A (electrical conductivity of a crystalline bar of MgO):

TABLE VII

t °C	$A = \times 10^{-6}$
800	0.01
900	0.10
1000	0.20
1050	0.34
1100	1.00
1150	2.60

These values are higher than those in Table VI, but are in fair agreement considering the difference in materal.

Acknowledgments

The author wishes to acknowledge the assistance of his co-workers, R. M. Shremp and V. R. Ostrander, for the major part of the laboratory work in connection with the preparation of this paper, especially for assistance in the petrographic examination of the numerous samples, and to Louis Navias and J. B. Austin for worthy suggestions.

LAVA CRUCIBLE COMPANY OF PITTSBURGH
ZELIENOPLE, PENNSYLVANIA

THE USE OF TALC AND PYROPHYLLITE IN SEMIVITREOUS DINNERWARE BODIES*

BY ELMO H. LINTZ

ABSTRACT

The use of talc and pyrophyllite in semivitreous dinnerware bodies is discussed. The effect of these materials on shrinkage, absorption, modulus of rupture, and moisture expansion are shown. The advantages obtained are better drying and firing properties, higher mechanical strength, and greater resistance to delayed crazing.

Part I

I. Introduction

Delayed crazing or the crazing in service of semivitreous dinnerware has been a source of considerable loss to the manufacturer as well as having its detrimental effect on the sales of this product. The advent of the high ball-clay type of ivory body has diminished the tendency of this type of dinnerware to craze. Owing to the variation in bisque firing, however, crazing occasionally occurs.

Because it has been definitely proved that delayed crazing is usually due to a permanent moisture expansion of the body and because such a marked improvement in resistance to delayed crazing in wall-tile type of bodies has been made by the use of talc and pyrophyllite, it was decided to study the effect of these materials in a semivitreous dinnerware body.

Two types of talc were selected for this study, a lime-bearing and a lime-free talc. The lime-free talc is a Manchurian talc and the lime-bearing talc, from St. Lawrence County, New York, is a product of alteration of tremolite. Analyses of these types are shown as follows:

	Manchurian	New York
SiO_2	59.70	55.90
MgO	34.01	30.70
Al_2O_3	1.10	0.70
Fe_2O_3	0.50	0.12
CaO	0.30	6.20
Na_2O		0.50
K_2O		Tr.
MnO		Tr.
B_2O_3		0.17
Loss on ignition	4.30	5.95

II. Experimental

(1) Bodies

Eight series of bodies of six members each were made up. New York State talc was used in series A to D, inclusive, and Manchurian talc in series E to H, inclusive. All bodies were computed on the dry basis. The composition of all the members in series E to H, inclusive, was the same as that in series A to D, respectively, except that Manchurian talc replaced the New York State talc.

	SERIES A					
Body	A-1	A-2	A-3	A-4	A-5	A-6
Bell's dark ball clay	25	25	25	25	25	25
Cooley ball clay	10	10	10	10	10	10
Cherokee Ga. clay	10	10	10	10	10	10
No Karb Ga. clay	10	10	10	10	10	10
Flint	35	35	35	35	35	35
N. C. feldspar	10	8	6	4	2	0
N. Y. State talc	0	2	4	6	8	10

*A thesis presented for the professional degree of Ceramic Engineer, Ohio State University, Columbus, Ohio, 1937. Received August 25, 1937.

SERIES B

Body	B-1	B-2	B-3	B-4	B-5	B-6
Bell's dark ball clay	30	30	30	30	30	30
Cooley ball clay	10	10	10	10	10	10
Cherokee Ga. clay	10	10	10	10	10	10
No Karb Ga. clay	10	10	10	10	10	10
Flint	30	30	30	30	30	30
N. C. feldspar	10	8	6	4	2	0
N. Y. State talc	0	2	4	6	8	10

SERIES C

Body	C-1	C-2	C-3	C-4	C-5	C-6
Bell's dark ball clay	35	35	35	35	35	35
Cooley ball clay	10	10	10	10	10	10
Cherokee Ga. clay	10	10	10	10	10	10
No Karb Ga. clay	10	10	10	10	10	10
Flint	25	25	25	25	25	25
N. C. feldspar	10	8	6	4	2	0
N. Y. State talc	0	2	4	6	8	10

SERIES D

Body	D-1	D-2	D-3	D-4	D-5	D-6
Bell's dark ball clay	35	35	35	35	35	35
Cooley ball clay	15	15	15	15	15	15
Cherokee Ga. clay	10	10	10	10	10	10
No Karb Ga. clay	10	10	10	10	10	10
Flint	20	20	20	20	20	20
N. C. feldspar	10	8	6	4	2	0
N. Y. State talc	0	2	4	6	8	10

Members E-1, F-1, G-1, and H-1 were not made up, inasmuch as they were duplicates of A-1, B-1, C-1, and D-1.

(2) Methods

The bodies were weighed (the proper correction for moisture having been made), blunged, and

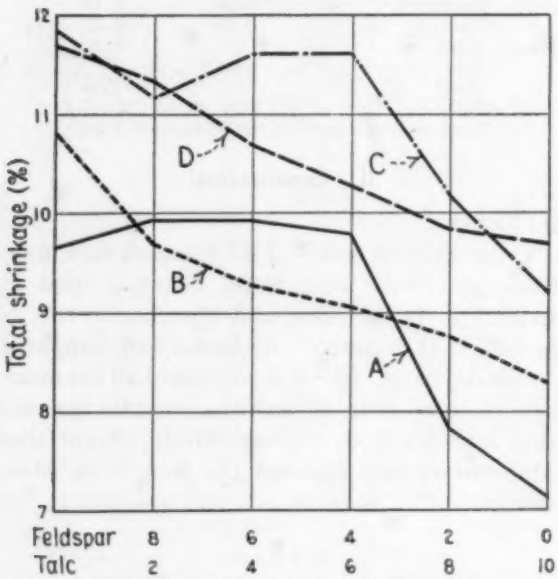

FIG. 1.—Lime-bearing talc series.

lawned through a 120-mesh sieve and filter-pressed in a small laboratory-size filter press. After aging for three days, the bodies were thoroughly wedged by hand. Bars, 1 by 1 by 7 inches, were made for tests on shrinkage and dry and fired modulus of rupture. Five bars, 1 by 1 by 4 inches, were made for permanent moisture determination. The remainder of the body was

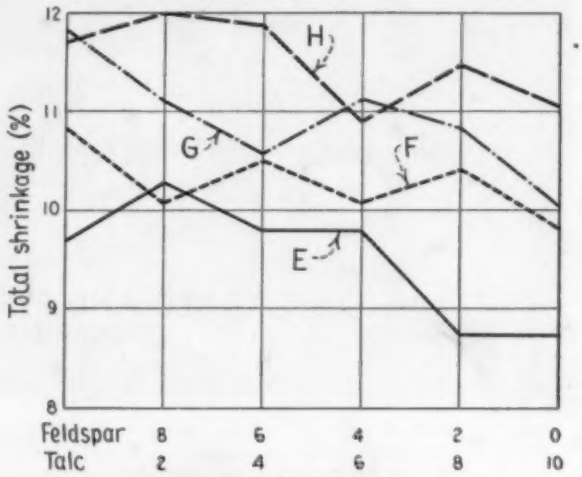

FIG. 2.—Lime-free talc series.

jiggered into 5-inch plates for the thermal shock test and the delayed crazing tests in the autoclave, as well as for observations on glaze fit, color, and warpage.

The dried bars and plates in each series were then fired through a commercial tunnel kiln. Cones, placed in the saggers with the ware, showed a variation in firing treatment of about one cone, the cone variation being from cones 8^2 to 9^2.

Fired shrinkage and modulus of rupture of the fired bars and water absorption were determined in accordance with the recommendations of the Standards Committee of the American Ceramic Society. The water absorption was taken as an average of five of the 5-inch plates and was expressed in percentage of the dry piece. The moisture-expansion bars were measured dry by means of a micrometer, graduated to read in ten thousandths of an inch, rigidly mounted in a frame equipped with a saddle to hold the specimen in the same relative position. Three readings were made on each specimen piece, and the average was taken. When the proper position of the piece was determined, these readings agreed quite closely. The bars were then subjected to an autoclave treatment of 150 pounds of steam pressure for three hours. After the autoclave treatment, the bars were removed and were measured again under the same conditions. The difference in length

was determined and the moisture expansion was expressed in percentage of the original length.

The remaining plates were sprayed with a production glaze and fired through the commercial glost kiln. Two plates from each series were subjected to the thermal-shock test by heating

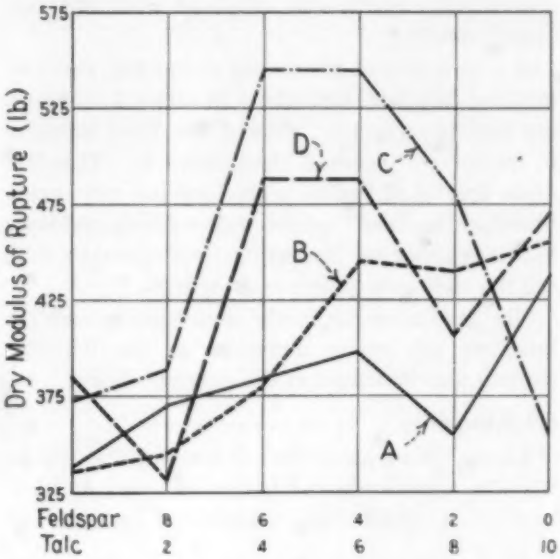

FIG. 3.—Lime-bearing talc series.

them to 200°C above tap-water temperature, holding for one hour, and then plunging them into tap water. Two glazed plates were put in the autoclave with the moisture-expansion bars and were given the same treatment.

The glaze used had the following composition:

$$\left.\begin{matrix}0.1600\ K_2O\\0.0512\ Na_2O\\0.4350\ CaO\\0.3560\ PbO\end{matrix}\right\}\ 0.298\ Al_2O_3\ \left\{\begin{matrix}2.95\ SiO_2\\0.291\ B_2O_3\end{matrix}\right.$$

TABLE I

GLAZE FIT CHART AS INDICATED BY EXAMINATION OF GLAZED PLATES IN DIFFERENT BODIES STUDIED

Series	Body A1	A2	A3	A4	A5	A6
A	NS	SL	SL	SB	SB	SHB
B	"	"	"	SL	"	"
C	"	NS	NS	"	"	"
D	"	"	"	NS	"	"
E	"	SB	SHB	SHB	SHB	"
F	"	SL	SB	SB	"	"
G	"	NS	SL	"	SB	"
H	"	"	"	SL	"	"

NS = no shivering.
SL = slight tendency to shiver on edges.
SB = shivered badly (especially on edge and foot of plate).
SHB = shivered badly; glaze left the surface; shattered so badly plates fell apart.

TABLE II

RESULTS OF THERMAL-SHOCK TEST

Series	Body 1	2	3	4	5
A	NCD	NCD	ED^2	C^5	C^3
B	C^3	ED^4	ED^4	D^3	C,D^2
C	C^2	C,ED^2	C^4	C^4	C^1
D	C^4	C^3	C^3	C^3	C,D^3
E	NCD	D^5			
F	NCD	C,D^2	D^2		
G	C^5	C^1	C,D^2	D^4	
H	C^4	D^1	D^1	D^1	C,D^1

NCD = no crazing or dunting.
ED = dunting slightly down from edge of plate.
D = dunting.
C = crazing.
The index number indicates the number of quenchings at which failure occurred, *i.e.*, C^5 = crazing on fifth quenching.

TABLE III

RESULTS OF AUTOCLAVE TEST

Series	Body 1	2	3	4	5
A	AC	NC	NC	NC	NC
B	"	A	"	"	"
C	"	NC	"	"	"
D	"	AC	"	"	"
E	"	NC			
F	"	"	NC		
G	"	A	"	NC	NC
H	"	A	"	"	"

AC = all plates crazed.
A = one plate crazed slightly; no crazing on others.
NC = no crazing.

III. Results

(1) Shrinkage

Figure 1 shows the effect of talc on the total shrinkage of the different bodies in series A, B, C,

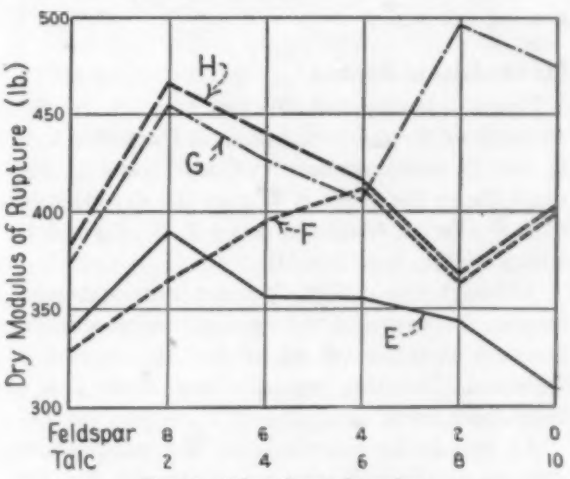

FIG. 4.—Lime-free talc series.

and D. Figure 2 shows the effect of lime-free talc on the total shrinkage of the different bodies in series E, F, G, and H.

Owing to the differences in water of plasticity in the bodies, both in the lime-bearing and in the lime-free series, the results are quite erratic. Only a general conclusion can be drawn here.

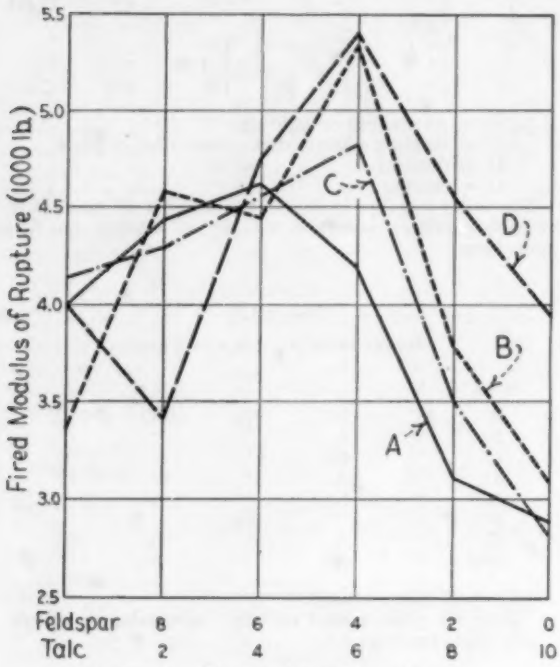

FIG. 5.—Lime-bearing talc series.

As shown in Figs. 1 and 2, the shrinkage decreases as the talc is increased at the expense of feldspar. This is more clearly shown in the lime-bearing talc series.

(2) Modulus of Rupture

Figure 3 shows the effect of talc on the dry strength of the different bodies in the series A, B, C, and D, which contain lime-bearing talc. Figure 4 shows the effect of talc on the dry strength of the different bodies in series E, F, G, and H, which contain lime-free talc.

Although the results obtained were somewhat erratic, there seemed to be a slight increase in dry strength as talc was increased at the expense of feldspar. This was generally true in the case of both talcs used.

As was to be expected, the dry strength increased as the ball clay was increased and flint was decreased.

Figure 5 shows the effect of lime-bearing talc on the fired strength of bodies in series A, B, C, and D. Figure 6 shows the effect of lime-free talc on the fired strength of bodies in series E, F, G, and H.

Fired strength increased with the addition of talc at the expense of feldspar up to a certain point and then rapidly decreased. In series A, the maximum strength was obtained with 4% talc and 6% feldspar, while in series B, C, and D, the maximum strength was obtained with 6% talc and 4% feldspar.

A comparison of the bodies in series E, containing lime-free talc, with those in series A, containing lime-bearing talc, showed the fired strength to be lower in series E than series A. This fact holds true in all bodies in the lime-free talc series. Small additions of lime-free talc replacing feldspar had less effect on increasing fired strength than did the additions of lime-bearing talc.

The fired strength in the lime-bearing and the lime-free talc series increased as the ball-clay content was increased at the expense of flint.

(3) Absorption

Figure 7 shows the effect of lime-bearing talc on the water absorption of bodies in series A, B, C, and D. Figure 8 shows the effect of lime-free talc

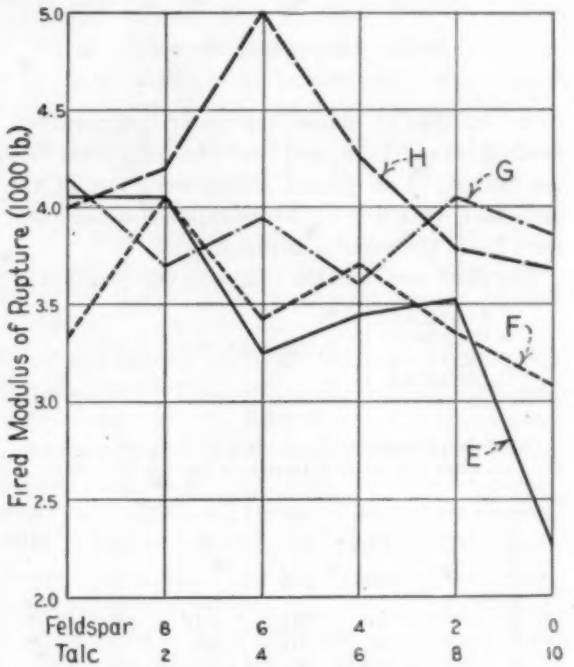

FIG. 6.—Lime-free talc series.

on the water absorption of bodies in series E, F, G, and H.

In series A, B, C, and D, the absorption was slightly decreased with the first addition of talc at

the expense of feldspar. Beyond point 3, the increase in absorption was quite rapid. As ball clay replaced flint in these series, however, the absorption was lowered and the fluxing action of a small addition of talc, as shown in body No. 2 of these series, was more pronounced as clay replaced flint.

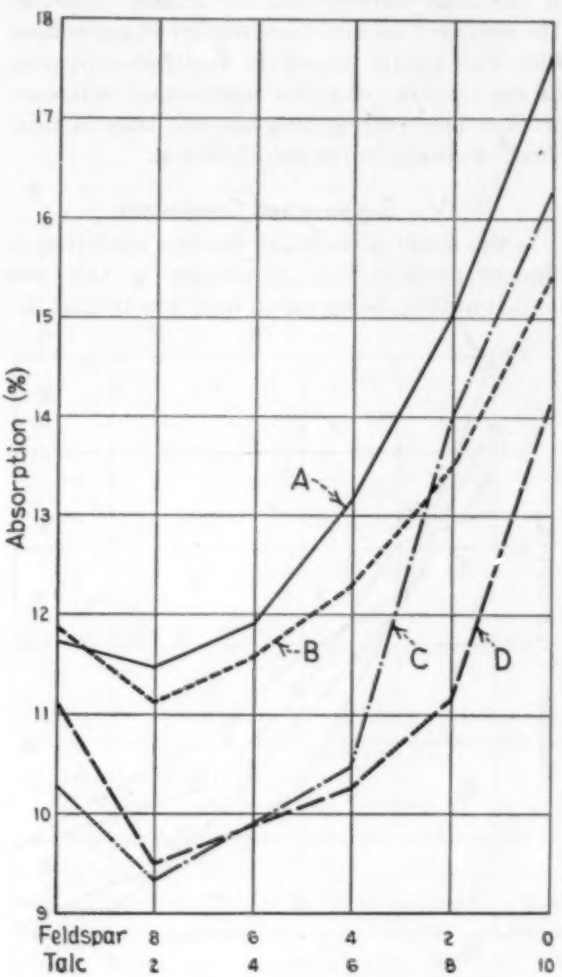

FIG. 7.—Lime-bearing talc series.

A comparison of Fig. 8 with Fig. 7 shows that the first addition of lime-free talc to the body does not lower the absorption as does the lime-bearing talc. Comparing all members of lime-bearing talc series with the corresponding members of the lime-free talc series, it is noted that in all cases where both feldspar and talc are in the body, the lime-bearing talc bodies show a lower absorption than the bodies containing lime-free talc.

(4) Permanent Moisture Expansion

Figure 9 shows the effect of lime-bearing talc on the moisture expansion, and Fig. 10 the effect of lime-free talc on moisture expansion.

Series, A, B, C, and D show that in each series the replacement of feldspar with talc lowers the moisture expansion. In general, replacing flint with ball clay also lowers the moisture expansion. This is to be expected as the absorption is also lowered as shown in Fig. 7.

Successive additions of lime-free talc to bodies in series E, F, G, and H also lower the moisture expansion. The rate of decrease, however, is not as rapid nor are the values as low as when the lime-bearing talc is added. From these results, it would appear that the presence of lime in the talc is more effective in lowering moisture expansion.

(5) Glaze Fit

Visual examination of the glaze on the plates as they came from the kiln (Table I) showed the effect of varying percentages of flint in the body.

In series A, which contains 35% flint, slight shivering was noted with the first addition of talc. As talc was increased at the expense of feldspar, shivering increased. In body No. 6, which contains no feldspar, the glaze shivered off the plates and they were shattered into small pieces.

In series B, where the ball clay was increased 5% at the expense of flint, bad shivering was not encountered until all but 2% of feldspar had been replaced with talc.

In series C, where an additional 5% flint had been replaced with ball clay, no shivering occurred until 6% of talc replaced feldspar, and in series D, which contained 20% flint, no shivering occurred until all but 2% of feldspar had been replaced with talc.

The bodies in series E, F, G, and H, which contained lime-free talc, shivered and shattered more than the bodies containing lime-bearing talc.

In series E, it is shown that all bodies containing talc shivered. Series F showed a slight improvement, and in series G, slight shivering occurred when 4% feldspar was replaced with talc. Series H showed very little improvement over series G.

These results would tend to prove that a reduction of flint has a marked influence on decreasing shivering and that a lime-bearing talc does not cause shivering to the extent that a lime-free talc does.

While shivering was decreased by increasing the ball clay at the expense of the flint, other properties of the body were affected to the extent that these bodies would not be suitable for a semivitreous tableware body. The increase in ball clay caused abnormal warping and poor drying properties, especially in the bodies containing 40 to 45% ball clay.

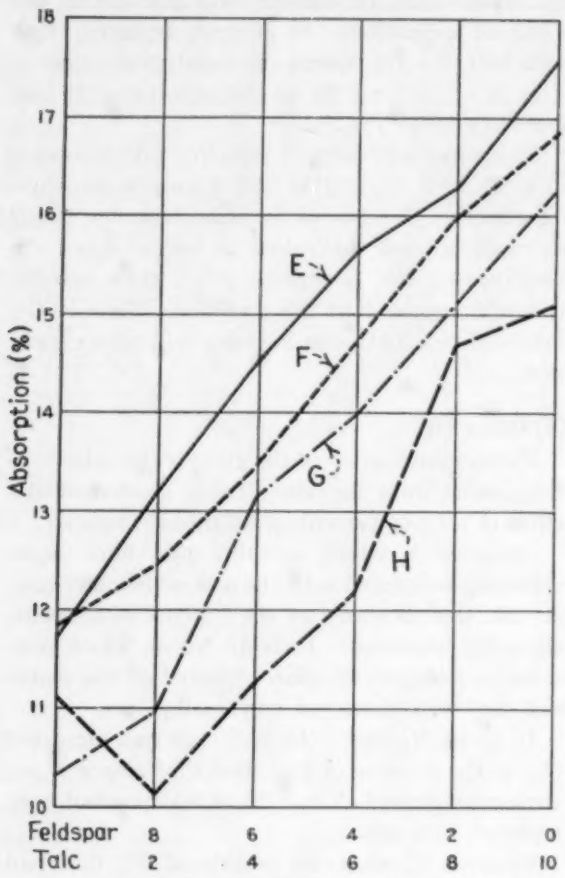

FIG. 8.—Lime-free talc series.

(6) Thermal Shock Test

Results of this test (Table II) indicate that the quenching temperature of the plates in each series was too high. All plates in all series either crazed or dunted before they had been quenched five times. It is possible that the bodies containing 20 to 25% flint might show some promise if their glaze had had a thermal expansion more in accord with the thermal expansion of the body.

(7) Autoclave Test

Delayed crazing as affected by talc is shown in Table III. Body No. 1 in each series, which contained no talc, crazed badly in the autoclave treatment. The addition of 2% talc in body No. 2, series A, C, D, E, and F, showed no crazing. Slight crazing occurred on one plate, body No. 2, series B, G, and H, probably due to a difference in absorption.

An addition of 4% or more of talc in all bodies of all series showed that no crazing occurred. The results in the autoclave test are in accordance with the results shown in moisture-expansion curves. There was no noticeable difference between lime-bearing and lime-free talcs in their effect on crazing in the autoclave test.

IV. Summary and Conclusions

In this study of the use of talc in a semivitreous dinnerware body, the percentage of talc was limited to 10%, being varied from 0 to 10% at the expense of feldspar in each series. The flint was decreased from 35 to 20% in 5% increments. In this manner, the effect of various percentages of talc and feldspar was studied with various percentages of flint.

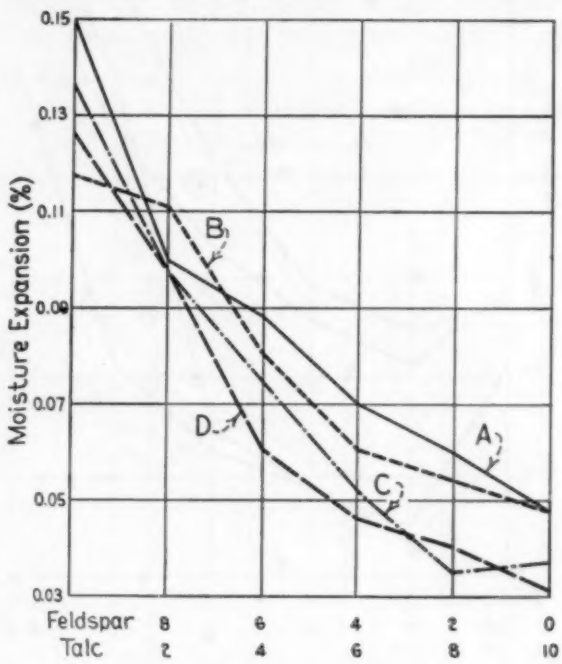

FIG. 9.—Lime-bearing talc series.

(1) Introduction of talc into a semivitreous dinnerware body may be expected to decrease shrinkage, fired strength, and permanent moisture expansion and to increase the absorption when fired to the customary temperature.

(2) Thermal expansion of the bodies containing talc was materially affected as shown in Table I (glaze-fit chart). Shivering occurs in the series highest in flint when talc is introduced at the expense of feldspar, decreasing as the flint is decreased and the clay is increased.

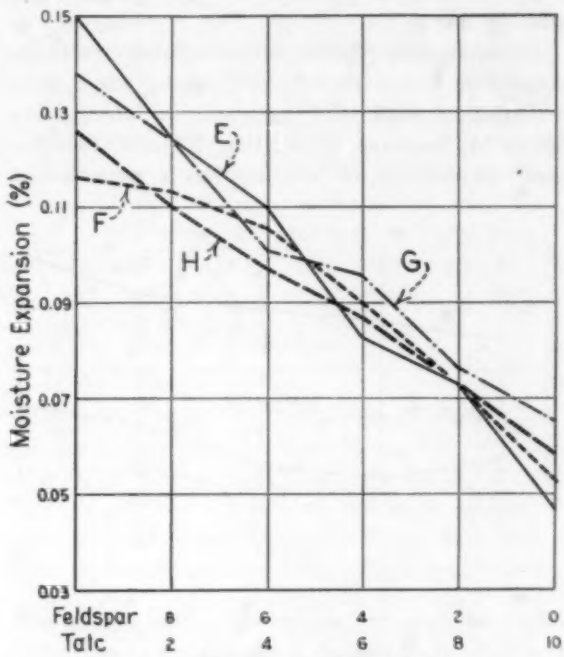

FIG. 10.—Lime-free talc series.

(3) The resistance to delayed crazing was increased with the addition of 5% or more of talc at the expense of feldspar.

(4) The lime-bearing talc proved to be more desirable than the lime-free talc. In a comparison of the bodies containing corresponding amounts of talc, those with lime-bearing talc had greater fired strength, lower absorption, less tendency to shiver, and lower moisture expansion than the bodies containing lime-free talc.

(5) No satisfactory bodies were developed in this series.

Part II

The next step in developing a suitable body was to replace part of the ball clay with pyrophyllite.[1] The following composition was reported:

SiO_2	70.15%	K_2O	1.54%
Al_2O_3	23.84	Na_2O	0.20
CaO	0.06	Fe_2O_3	0.07
MgO	0.02	Ignition loss	4.00

[1] The pyrophyllite used was supplied by the R. T. Vanderbilt Co., under the trade name of Pyrax pyrophyllite.

A series of bodies was made, and the physical properties were determined in the same manner as described in the first series. Series K shows the effect of varying percentages of pyrophyllite and flint. Series M shows the effect of an addition of a small percentage of whiting to the bodies in series K.

SERIES K

Body	K-1	K-2	K-3	K-4	K-5
Bell's dark ball clay	16	16	16	16	16
Bell's Dresden ball clay	16	16	16	16	16
Cherokee Ga. clay	15	15	15	15	15
N. C. clay	8	8	8	8	8
N. Y. State talc	6	6	6	6	6
N. C. feldspar	6	6	6	6	6
Pyrax pyrophyllite	16.5	14.5	12.5	10.5	8.5
Flint	16.5	18.5	20.5	22.5	24.5

SERIES M

Body	M-1	M-2	M-3	M-4	M-5
Bell's dark ball clay	16	16	16	16	16
Bell's Dresden ball clay	16	16	16	16	16
Cherokee Ga. clay	15	15	15	15	15
N. C. clay	8	8	8	8	8
N. Y. State talc	6	6	6	6	6
N. C. feldspar	6	6	6	6	6
Pyrax pyrophyllite	15	13	11	9	7
Flint	16.5	18.5	20.5	22.5	24.5
American whiting	1.5	1.5	1.5	1.5	1.5

(1) Shrinkage

Figure 11 shows the effect of varying percentages of flint and pyrophyllite in series K and, in series M, the effect of an addition of a small percentage of whiting.

In series K, the addition of flint at the expense of pyrophyllite showed little effect on total shrinkage, while in series M, the effect of the whiting is

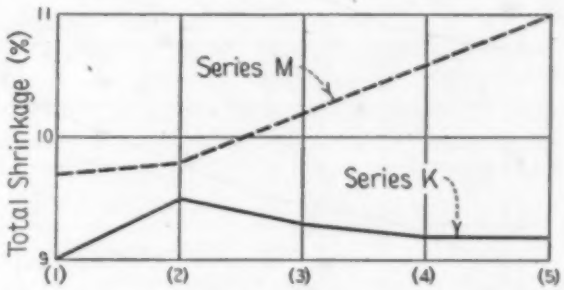

FIG. 11.

quite pronounced. As flint replaces pyrophyllite, the shrinkage is increased from 9.7% in body 1 to 11.0% in body 5.

(2) Modulus of Rupture

Figure 12 shows the effect of varying percentages of flint and pyrophyllite in series K and, in series M, the effect of a small addition of whiting.

As in the case of shrinkage, the increase of flint at the expense of pyrophyllite showed little effect on the fired modulus of rupture, but when the whiting was added, the effect was noticeable.

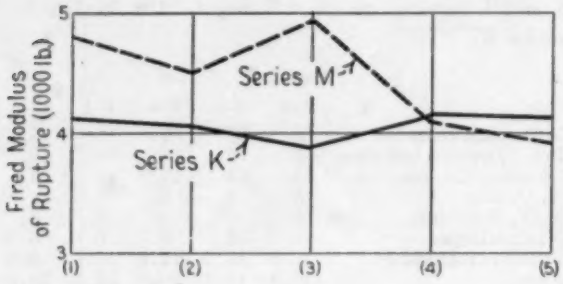

FIG. 12.

Stronger bodies were obtained, the strongest occurring in body 3, series M; after that the strength rapidly diminished.

(3) Absorption

Figure 13 shows the effect on absorption of varying percentages of flint and pyrophyllite in series K and of the whiting addition in series M.

In series K and M, the absorption increased as flint replaced pyrophyllite in the body. As

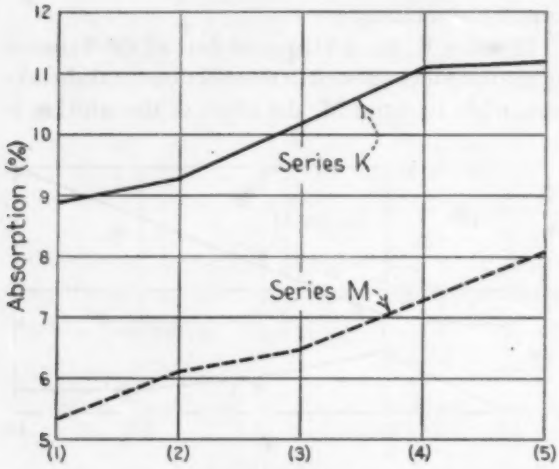

FIG. 13.

shown in series M, however, the addition of whiting had a marked fluxing action when fired to cone 9. This was also evident in the plates made from these bodies, inasmuch as a pronounced dropping of the rims was noted.

It is interesting to note here that, although the shrinkage increased as flint was increased in series M, the absorption did not decrease as would normally be expected.

(4) Moisture Expansion

Figure 14 shows the effect on moisture expansion of varying percentages of flint and pyrophyllite in series K and, in series M, the addition of whiting.

In both series, the moisture expansion was increased as flint replaced pyrophyllite, which is in accordance with the increase in absorption. Series M, however, shows that the addition of a small percentage of whiting has a pronounced

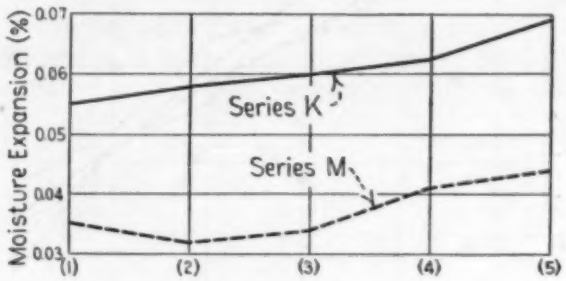

FIG. 14.

effect on moisture expansion. This agrees with the findings of Sproat in his studies of pyrophyllite in wall-tile bodies.[2] Much lower values were obtained in all bodies of series M compared to the bodies in series K.

(5) Glaze Fit

Examination of the plates, which had been glazed with the same glaze as previously used, showed that no shivering or crazing occurred on any of the plates in series K-1 and K-2. In series K-3 and K-4, four plates out of ten shivered slightly; in series K-5, five plates out of ten shivered slightly.

In series M, no shivering occurred on any of the plates in any of the series. A comparison of the results of these two series with the results in Table I shows that a definite improvement in tendency to shiver was made by substituting pyrophyllite for part of the ball clay and by keeping the talc and feldspar constant at 6%. Further improvement was made by the addition of a small percentage of whiting.

---

[2] Ira E. Sproat, "Use of Pyrophyllite in Wall-Tile Bodies," *Jour. Amer. Ceram. Soc.*, **19** [5] 135–42 (1936).

(6) Thermal Shock Test

The thermal shock test made at 200°C, as in the first series, indicates that the temperature is also too high for this series. All plates in series K and M dunted on the first or second quenching. When the temperature was lowered to 150°C, the only dunting which occurred in any of the members of series K and M occurred in series K-5, which had the highest flint and lowest pyrophyllite content.

(7) Autoclave Test

No crazing occurred in the autoclave treatment on any of the plates of series K or M. This result agrees with the previous findings that a body having less than 0.07% permanent expansion will withstand 150 pounds pressure in the autoclave for three hours without crazing.

(8) Color

The color of the bodies containing pyrophyllite was not so good as the straight talc bodies. In series K, some specking was noted in the bodies higher in pyrophyllite. The color of the bodies of series M was unsatisfactory. They were gray-white with marked specking. This was caused by improper cleaning of the pyrophyllite. Passing the pyrophyllite over a magnetic separator no doubt would improve the color of the bodies.

The drying and firing properties of the bodies in series K and M were satisfactory, except that the plates in series M had a tendency to drop; otherwise all bodies dried and fired without any appreciable warping. Elimination of rim-dropping was accomplished by reducing the whiting to 1% and by increasing the North Carolina clay at the expense of the Georgia clay. The body which gave the best results is as follows:

	(%)
Bell's dark ball clay	16
Ky. No. 4 ball clay	16
Cherokee Ga. clay	13
Harris Lunday N. C. clay	10
N. Y. State talc	6
N. C. feldspar	6
Pyrax pyrophyllite	13
Flint	19
American whiting	1

(9) Results and Conclusions of Part II

In the study of the use of talc and pyrophyllite in a semivitreous dinnerware body, the percentage of feldspar and talc remained constant at 6% each, and the percentages of flint and pyrophyllite were varied. The study of an addition of 1.5% whiting was also included.

(1) Total shrinkage and fired modulus of rupture were not materially affected as the flint was increased at the expense of pyrophyllite.

(2) Absorption and moisture expansion increased as flint replaced pyrophyllite.

(3) The introduction of whiting had a marked influence on the body. Shrinkage increased as flint replaced pyrophyllite. Higher modulus of rupture values were obtained up to 20.5% flint, but further additions of flint at the expense of pyrophyllite decreased the fired strength. Much lower absorption and moisture expansion values were obtained with the use of whiting.

(4) Less shivering resulted when pyrophyllite was used in combination with talc; the shivering was entirely eliminated when whiting was added to the bodies.

(5) Bodies containing pyrophyllite in combination with talc were equally resistant to delayed crazing as compared to bodies containing only talc.

(6) A semivitreous dinnerware body can be developed using talc and pyrophyllite in combination with a small percentage of whiting which will have good drying and firing properties, high mechanical strength, and greatly improved resistance to delayed crazing as compared to the present type of bodies in use.

Taylor, Smith, & Taylor Company
Chester, West Virginia

WANTED: ABSTRACTERS FOR THESE JOURNALS

The following journals contain material of interest to readers of *Ceramic Abstracts*. An abstracter for any of these journals should (1) have the journal available in his personal library or in a public, laboratory, or school library to which he has access, (2) be prepared to submit the abstracts regularly each month, and (3) possess a reading knowledge of the language in which the publication is printed. Address all requests for assignments to the office of *Ceramic Abstracts*, 2525 North High St., Columbus, Ohio. Journals will be assigned to those first requesting them.

Acta Physicochimica U.R.S.S.
American Journal of Pharmacy
American Review of Tuberculosis
American Soil Survey Assn., Report of Annual Meeting
Anales de la Sociedad Española de Física y Química
Annalen der Chemie
Annales agronomiques
Arch. für Hygiene und Bakteriologie
Architecture
Architecture & Building
Archives de Minéralogie de la Société des sciences et des lettres de Varsovie
Art et Decoration
Belg. Netherl. Klei Ind.
Bibliografia Italiana
Building Economy
Bull. Acad. Roy. Belgique
Bulletin of the Chemical Society of Japan
Bulletin de l'Institut du Pin
Bulletin de la Section Scientifique de l'Académie Roumaine
Bulletin de la Société Chimique du Royaume de Yougoslavie
Canadian Public Health Jour.
Cemento
Ceramica
Clay Products News
Compt. Rend. Inst. Geol. Roumanie
Corriere dei Ceramisti
Deutsche Goldschmiede-Zeitung
Deutsche Wollen Gewerbe
Documentation Scientifique
Electricité
Farben-Zeitung
Feinmechanik & Präzision
Fette und Seifen
Forschung auf dem Gebiete des Ingenieurwesens and Forschungsheft
Gelatine, Leim, Klebstoffe
Glück Auf
Hutnik
Illustr. Ztg. Blech-ind.
Industritidning Norden
Ingénieur Chimiste
Ingegnere
Ingenieria [Mexico]
Ingeniøren
Inst. Mekhanicheskoi Obrabotki Poleznuikh Isokopaemuikh Mekhanobr
Jernkontorets Annaler
Journal of the British Society of Master Glass Painters
Journal of the Fuel Society of Japan
Jour. Roman Studies
Journal of the South African Chemical Institute
Journal of the Western Society of Engineers
Keramic Tile Journal
Khimicheskoe Mashinostroenie
Klei
Klinische Wochenschrift
Koks i Khimiya
Kolloidnyi Zhurnal
Legkie Metally
Lerindustrien
Magyar Chemiai Folyóirat
Mathematischer und naturwissenschaftlicher Anzeiger der ungarischen Akademie der Wissenschaften
Med. du Travail
Metall & Erz
Metallwaren-Industrie und Galvano-Technik
Mineral'noe Syr'e
Mitt. Forschungsinst für Electro-Wärmetech (Hannover)
Mon. Phys. Phys.-Chem. Glass (Moscow)
Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen, Jahresbericht über das Geschäftsjahr, Mathematisch-physikalische Klasse
Naturwissenschaften
Natuurwetenschappelijk Tijdschrift
Nauchnye Zapiski po Sakharnoĭ Promyshlennosti
Nitrocellulose
Nova Acta Leopoldina
Oesterreichische Chemiker-Zeitung
Optiko-Mekh. Prom.
Paint Manufacture
Paint, Oil & Chemical Review
Periodico di Mineralogia (Rome)
Photographic Abstracts
Proceedings Royal Academy of Sciences of Amsterdam
Proc. Highway Research Board
Proc. Imperial Academy [Tokyo]
Proceedings of the Iowa Academy of Science
Przemysl Chemiczny
Pub. Nat. Bur. Econ. Research, Inc.
Reichsarb.-Bl.
Repts. Imp. Ceram. Expt. Inst.
Reports of the Imperial Fuel Research Institute, Japan
Reports of the Imperial Industrial Research Institute, Osaka, Japan
Ricerca Scientifica
Roczniki Chemji
Russko-Germanskiĭ Vestnik Nauki i Tekhniki
Schweizer Brauerei Rundschau
Scientific Journal of the Royal College of Science
Sitzungberichte der Akademie der Wissenschaften in Wien, Mathematische-Naturwissenschaftliche Klasse
Soap
Sveriges Geol. unders
Technische Blätter
Technisches Gemeindeblatt
Teknisk Tidskrift
Teknisk Ukeblad
Trans. Inst. Chemical Engineers (London)
Trans. State Institute of Applied Chemistry [U.S.S.R.]
Trudy Ivanovskogo Khimiko-Technologicheskogo Inst.
Trudy Vsesoyuznogo Mendeleevskogo S'ezda
United States Department of Agriculture Publications
University of North Carolina, Eng. Expt. Sta. Bull.
Verhandel. Akad. Wetenschappen Amsterdam, Afdeel. Natuurkunde
Wärme
Wärme- und Kälte-Technik
Waseda Applied Chemical Society Bulletin
Z. Anorg. & Allgem. Chem.
Zeitschrift für Metallkunde
Zeitschrift für Physik
Zeitschrift für Praktische Geologie
Zhurnal Obshcheĭ Khimii
Zhurnal Tekhnicheskoĭ Fiziki
Ziegelwelt
Zitein-SO
Z. Physik. Chem.
Z. Ver. Deut. Ing.

CERAMIC ABSTRACTS

Compiled by the

AMERICAN CERAMIC SOCIETY

Ross C. Purdy, Editor

Abstracters: J. B. Austin, A. A. Ayars, L. R. Barrett, A. C. Bevan, W. H. Bruckner, P. Budnikoff and E. Stefanowski, J. C. Chaston, W. M. Cohn, M. V. Condoide, M. E. Cook, P. S. Dear, Maurice Delangre, R. W. Devillers, A. H. Emery, W. D. Foster, V. D. Fréchette, J. L. Gallup, J. D. Gat, W. H. Gitzen, H. C. Goudy, Jr., P. E. Grotts, Max Hartenheim, J. J. Hazel, F. G. Heck, R. A. Heindl, P. G. Herold, G. M. Hutt, J. F. Hyde, Herbert Insley, C. B. Jenni, B. Z. Kamich, B. E. Kinkulkin, S. Kondo, Walther Kurz, E. H. McClelland, F. P. Peters, G. M. Petersen, C. J. Phillips, J. G. Phillips, Alexis Pincus, M. E. Poor, Katherine Reed, H. K. Richardson, B. C. Ruprecht, A. B. Searle, Stanford Setchell, M. C. Shaw, G. R. Shelton, H. E. Simpson, A. P. Som, E. W. Stenzel, H. H. Stephenson, A. G. Stern, B. H. Strom, L. E. Thiess, Hans Thurnauer, E. J. Vachuska, F. E. Vaerewyck, F. J. Zvanut.

The bold-face number following the journal name is the volume; the issue number is in brackets, followed by the page numbers, then the year in parentheses.

June, 1938
17—6

Abrasives

Abrasion of cast iron and effect of various elements thereon. Shiro Kusunose. *Tetsu-to-Hagane*, **23**, 23–39 (Jan. 25, 1937); *Metals & Alloys*, **8** [11] MA700 (1937).—K. carried on original research to determine the kind of cast Fe that offers abrasion resistance and yet is economical. An abrasion-testing machine was devised with which precise measurements are made and from the results of which cast irons considered to have the best compositions are prepared. Cast irons containing more than 3.5% C (Si + C $\leq$ 5.5%) are remarkably less resistant as compared with those containing 3% C (Si + C $\leq$ 5.0%). In ordinary pearlitic irons, abrasion resistance increases with the tensile strength. High C cast Fe (about 3.5% C) shows markedly increased resistance with an addition of P, but the increase is less in the case of low C cast Fe. Ni and Cr increase abrasion resistance.

Abrasive cutting off. Anon. *Automobile Engr.*, **27**, 18–19 (Jan., 1937); *Metals & Alloys*, **8** [12] MA733 (1937).—An economical procedure in cutting with abrasives is discussed, and the correct and incorrect methods of cutting section stock are shown. The best surface speed for bakelite-bonded wheels is 15,000 to 16,000 ft./min.; rubber-bonded wheels may safely be run at about 8000 ft./min.

British roll-grinding machines. Anon. *Iron & Steel Ind.*, **10** [12] 531–32 (1937).—Churchill precision grinding machines are designed for grinding both bodies and necks of rolls with exact concentricity. The point of contact between the roll and the grinding wheel is always visible to the operator, and constant speed is maintained by electric control. E.H.McC.

Finishing cemented carbides. H. R. Power. *Modern Machine Shop*, **9**, 108–12 (April, 1937); *Metals & Alloys*, **8** [11] MA680 (1937).—Surfaces that have been hardened to a very high Brinell number, such as W, Ta, or Ti carbides, can be finished by the use of Al_2O_3 wheels with speeds of 4000 to 4500 ft./min.; the pressure of the piece against the wheel should be light to avoid excessive heating and wheel wear. Practical suggestions on equipment and procedure are given.

Finishing welds in stainless steel. Anon. *Oxy-Acetylene Tips;* reprinted in *Sheet Metal Worker*, **28** [Nov.] 31–33; [Dec.] 35–37 (1937); *Metals & Alloys*, **9** [3] MA171 (1938).—Correct methods for grinding, polishing, and buffing are given.

Fundamental conditions for proper working of roll-grinding machines for cold rolling mills. Otto Emicke and Heinz Benad. *Kalt-Walz-Welt* (Supplement to *Drahtwelt*, **20** (March 27, 1937)), pp. 11–15; *Metals & Alloys*, **9** [3] MA150 (1938).—The quality of the rolls, the operation of the grinder, and the vibration in the grinding machine are stressed.

Grinding in the foundry; a duplex high-speed machine. Anon. *Iron & Steel Ind.*, **11** [5] 194–95 (1938).—By using synthetic-bonded wheels running at peripheral speeds as high as 9500 ft./min., it has been possible to increase output by as much as 400% in the grinding of iron and steel castings. With a single-speed machine, uniform peripheral speed is impossible as the wheel wears down. A new variable-speed machine (Luke & Spencer, Manchester, England) is described which insures uniform rim speed until the wheel is worn down to the clamping plates. E.H.McC.

Polishing and buffing of thin tin coatings. Anon. *Metallwaren-Ind. & Galvano-Tech.*, **35**, 421–22 (Oct. 15, 1937); *Metals & Alloys*, **9** [3] MA170 (1938).

Selection of abrasive disks. Anon. *AWF-Mitteilungen*, **1937**, No. 5, pp. 51–52; abstracted in *Referat. Sili-*

katliteratur, **4** [7] 4247 (1937).—Basic relationships between abrasives and their use, granulation, bonding, hardness, and structure are discussed in detail. M.V.C.

PATENTS

Abrading and analogous rotary tool machines. Liberty Shoes, Ltd., and W. Banner. Brit. 481,937, March 30, 1938 (Sept. 16, 1936).

Abrading apparatus. K. H. Bowen (Columbian Rope Co.). U. S. 2,113,106, April 5, 1938 (Sept. 22, 1937).

Abrasive article and method of manufacturing. H. C. Martin and F. A. Upper (Carborundum Co.). U. S. 2,114,229, April 12, 1938 (April 11, 1935). The method of making resin-coated abrasive grains comprises preparing a mixture of abrasive grains coated with a pulverized resin and a plasticizing agent therefor and aging the mix at a temperature materially below the melting point of the resin and in an atmosphere having an aqueous vapor pressure not substantially in excess of 16 millimeters of mercury to ripen the bond and cause it to form firm adherent films about the individual granules.

Abrasive body and method of making. E. E. Novotny (Stokes & Smith Co. (Durite Plastics Division)). U. S. 2,111,248, March 15, 1938 (Sept. 4, 1929).

Abrasive member and method of making. D. S. Hubbell (H. H. Robertson Co.). U. S. 2,113,729, April 12, 1938 (Feb. 5, 1937). An abrasive member comprising particles of abrasive material and a binder therefor comprising the reaction product of a magnesium oxychloride cement containing, in an amount less than the amount of the cement, a reagent selected from the group comprising finely divided copper and cuprous oxide, the abrasive member being characterized by a high strength, volume constancy, and freedom from damage by water or contact with compositions containing lime.

Abrasives. Carborundum Co. Fr. 815,704, July 21, 1937; *Chem. Abs.*, **32**, 1890 (1938).—A solidified binder for the abrasive grains comprises one or more polymerized vinyl compounds, which contain sufficient OH groups to be soluble or dispersable in water, or the reaction product of one or more polymerized vinyl compounds of this kind and a hardening or insolubilizing agent. The binder may be a polyvinyl alcohol, a partly hydrolyzed polyvinyl compound, or a polymerized vinyl ester of a hydroxy acid.

Alkali silicate cement. Peter de Leeuw (Carborundum Co.). U. S. 2,114,166, April 12, 1938 (Oct. 4, 1935). A bonded article consists of granular material and a binder therefor, the binder consisting of the thermal reaction products, at temperatures of approximately 275° to 385°F, of from 55 to 65% of an alkali silicate, having an alkali-silica ratio of approximately 1:2, and from 35 to 45% of a modifier consisting of 40 to 80 magnesia, 10 to 60 amorphous silica, 0 to 30 zinc oxide, and 0 to 25% finely divided inert filler, the article having a decrease in strength of less than 20% after prolonged immersion in water.

Alkali silicate cements and articles bonded by such cements. Carborundum Co. Brit. 482,307 and 482,308, April 6, 1938 (Oct. 4, 1935).

Boron carbides. I. G. Farbenind. A.-G. Fr. 817,029, Aug. 24, 1937; *Chem. Abs.*, **32**, 1589 (1938).—A mixture of H_3BO_3 and C is heated in an electric arc. Methods of procedure are indicated.

Centerless grinding machines. J. E. Bergstrom. Brit. 481,846, March 30, 1938 (June 22, 1937).

Device for adjusting the grinding disk of grinding machines, particularly gear-grinding machines. L. S. E. Ellis (Maag-Zahnrader und-Maschinen Akt.-Ges.). Brit. 481,021, March 16, 1938 (Aug. 31, 1936).

Dressing apparatus. Albert Vuilleumier (General Motors Corp.). U. S. 2,113,186, April 5, 1938 (Oct. 5, 1934).

Dust confiner and collector for grinding and polishing machines. N. E. Hudson. U. S. 2,111,782, March 22, 1938 (Jan. 21, 1936).

Flat grinding mechanism for carding machines. W. W. Meredith. U. S. 2,112,676, March 29, 1938 (June 25, 1937).

Glass feeder and method. B. D. Brown (Capstan Glass Co.). U. S. 2,113,249, April 5, 1938 (Dec. 28, 1935).

Grinding cam shafts. F. Deckel (F. Deckel, Präzisionsmechanik und Maschinenbau). Brit. 481,722, March 30, 1938 (Oct. 27, 1936).

Grinding device. William Geveke. U. S. 2,114,106, April 12, 1938 (August 20, 1935). A device for grinding knives and scissors is described.

Grinding machine. C. H. Amidon (Norton Co.). U. S. 2,113,363, April 5, 1938 (Feb. 6, 1937).

Grinding machine headstock. C. H. Amidon (Norton Co.). U. S. 2,113,362, April 5, 1938 (Jan. 21, 1937).

Grinding machine work-clamping mechanism. H. A. Silven and C. G. Flygare (Norton Co.). U. S. 2,113,388, April 5, 1938 (Dec. 24, 1936).

Grinding and polishing apparatus. W. R. Akans. U. S. 2,111,955, March 22, 1938 (Aug. 27, 1936).

Grinding wheels and other abrasive articles. Norton Grinding Wheel Co., Ltd. Brit. 482,351, April 6, 1938 (Sept. 28, 1935).

Hone. W. D. Schmidt (Heald Machine Co.). U. S. 2,112,120, March 22, 1938 (Sept. 14, 1936).

Honing machine. A. M. Johnson (Barnes Drill Co.). U. S. 2,111,784, March 22, 1938 (Sept. 20, 1934).

Lapping toothed gears. W. J. Tennant (Carborundum Co.). Brit. 480,720, March 9, 1938 (Aug. 29, 1936).

Machine for grinding crank pins. Norton Co. Brit. 480,888, March 16, 1938 (Oct. 18, 1935).

Machine for grinding and sharpening broaches. W. G. Baldenhofer (Thompson Grinder Co.). U. S. 2,113,287, April 5, 1938 (June 14, 1937).

Manufacture of bonded articles. M. L. Whitacre (Carborundum Co.). U. S. 2,114,160, April 12, 1938 (Oct. 4, 1935). A bonded abrasive article comprising abrasive grain and a bond therefor consisting essentially of the thermal reaction products of an alkali silicate and a modifier comprising zinc oxide, pulverized flint, and an oxide of the group consisting of CuO, MgO, SrO, BaO, Hg_2O, TiO_2, Fe_3O_4, Co_2O_3, NiO, and amorphous SiO_2.

Manufacture of mixed carbides and of articles made therefrom. Keramet Ges. für Keramisches Metall Ges. Brit. 481,876, March 30, 1938 (Nov. 11, 1935).

Manufacturing grinding and polishing bodies. Rudolf Thilenius and Josef Schneider (Deutsche Gold-

und Silber-Scheideanstalt vorm. Roessler). U. S. 2,113,185, April 5, 1938 (Nov. 6, 1934). A process for the manufacture of abrasive bodies having artificially produced voids from abrasive materials and synthetic resin binders comprises the steps of mixing the abrasive granules and a resinous binding medium which will develop gas upon heating, subjecting the mixture to treatment whereby the softening point of the resin is elevated, placing the mixture in a closed mold which permits the escape of gas and air but from which the mixture can not escape, heating the mixture in order to develop gas therein and to substantially fill the mold, and then further heating the resulting product until solidification occurs.

Means for dressing grinding disks. ALFRED RICKENMANN AND EUGEN KREIS (Reishauer-Werkzeuge Akt.-Ges.). U. S. 2,112,679, March 29, 1938 (Jan. 6, 1936).

Metal carbides. COMPAGNIE DES MEULES NORTON (SOC. ANON.). Fr. 815,929, July 26, 1937; *Chem. Abs.*, **32**, 1589 (1938).—Abrasive carbides are made by putting a mixture of C and appropriate metal oxide in a closed furnace around an electric resistance, passing a current through the resistance to heat the central zone of the charge and progressively to form an ingot of carbide while maintaining a nonoxidizing atmosphere in the furnace. The ingot is cooled out of contact with air.

Production of grinding rings and grinding cylinders from emery and a binding medium of raw rubber. HARRY RANDALL. U. S. 2,113,142, April 5, 1938 (July 6, 1937).

Resurfaceable hone or file. F. M. FROEMMING. U. S. 2,112,152, March 22, 1938 (May 7, 1937).

Shears-sharpening machine. W. A. MINI. U. S. 2,111,868, March 22, 1938 (Feb. 17, 1936).

Tool for lapping the disk faces of valves on their seats. BABCOCK & WILCOX, LTD., AND J. H. GIBSON. Brit. 480,553, March 9, 1938 (March 19, 1937).

Valve-grinding machine. H. A. SILVEN (Norton Co.). U. S. 2,113,387, April 5, 1938 (May 2, 1936).

Art and Archeology

Basic materials and their compounds used as pigments in pottery, glass, and enamelware. JOSEF WOLF. *Sprechsaal*, **70** [48] 601–603; [49] 612–14; [50] 625–27 (1937).—W. gives a detailed description of all elements used as pigments in the ceramic industry together with their compounds and characteristics. M.V.C.

Ceramic colors. RUDOLF HOHLBAUM. *Glashütte*, **67** [41] 633–34; [43] 660–62; [44] 677–79 (1937).—H. gives a comprehensive review and a classification of various ceramic pigments and surface colors, transparent and opaque enamel colors and glazes, and their composition and use. M.V.C.

Church windows and leaded panels from R. Lardeur. ANON. *Glaces & Verres*, No. 53, pp. 9–10 (1937).—In composing his panels Lardeur makes use of glass and lead only, excluding from his work painted glass or similar artifice. Illustrated. R.W.D.

Contemporary pottery artists in Holland. ANON. *Studio* [London], **114** [536] 280–81 (1937).—Designs in pottery by Chris Lanooy and Lea Halpern and designs in glass from the Leerdam factory by K. P. C. de Bazel and A. D. Copier are illustrated. H.H.S.

Glass painting in the Baltic states. J. H. *Clarté*, **10** [11] 11–12 (1937).—The industry of painting glass panels flourished in the Baltic states prior to the World War, when a great number of pieces of art were exported to Russia. It was practiced chiefly by the aristocratic class, and many specimens of painted panels bear the coat of arms of the painter. Illustrated. R.W.D.

Glazing. E. KUNSTMAN. *Feinmechanik & Präzision*, **45**, 250 (1937); abstracted in *Chem. Zentr.*, **1938**, i, 399.—Methods of glazing various types of ware are analyzed. M.V.C.

Raynor Hoff. ANON. *Clay Prod. Jour. Australia*, **5** [2] 3 (1937).—Born on the Isle of Man 43 years ago, H. came to Sydney in 1924 and became director of applied arts (including ceramics) at the Sydney Technical College. His greatest work was the Anzac Memorial, Sydney. He died Nov. 19, 1937. H.H.S.

Imperial Vienna porcelain. Ferdinand Bloch-Bauer collection. WOLFGANG BORN. *Connoisseur*, **97** [415] 129–31 (1936).—This is the most valuable and extensive collection of porcelain in the classic style from the Imperial Viennese Factory and represents the height of the development of Viennese porcelain. Bloch-Bauer has also collected a considerable number of rococo porcelain sculptures which are very important historically. This factory, the oldest except one in Europe, was founded in 1718, 8 years after Meissen, by Claudius Innocentius Du Paquier under whom the forms and decoration were either the habitual forms of Austrian baroque or imitations of Far Eastern examples. It was taken over by the Austrian Government in 1744 and rococo forms influenced the studios of the factory. The innovation of having every piece signed with a trademark, the Austrian "Bindenschild" pressed into the soft porcelain body, gave the name "beehive porcelain." After 1749 the body was improved by using Hungarian kaolin and the new product had the Bindenschild in blue, painted under the glaze. A transition to Louis XVI style came about 1770. The "Bindenschild with Crown" mark probably indicated that the objects so marked were to be first at the disposal of the Imperial Court. In 1785 Baron Sorgenthal was nominated by Joseph II as independent director of the factory. He raised it to international importance in this period of classic taste. The porcelain was then marked with the last two numerals of the date, and after 1800 the last three were used. The techniques of gold relief and of luster are specialties of the Viennese Factory. "Leithner Blue," a cobalt blue, was invented in 1792 by the painter and chemist, Leithner. At the end of the 18th Century, miniature copies of the famous pictures came into fashion as decoration. Baron Sorgenthal died in 1805, but the Viennese Factory existed until 1864 although its prime is

coupled with the name of Sorgenthal. It has also produced later works which deserve great respect for their quality and originality. Illustrated. M.E.P.

Jobless find outlet in ceramics. ANON. *Bull. Amer. Ceram. Soc.*, **17** [4] 181–82 (1938).

Maya and Peruvian ceramics. MAURICE RIES. *Bull. Amer. Ceram. Soc.*, **17** [4] 178–81 (1938).

Neolithic pottery of the Thames Valley. A. D. LACAILLE. *Notes & Queries*, **173** [21] 361 (1937).—A neolithic pottery saucer and some shards, found at Iver in Buckinghamshire, form an important addition to the Thames Valley pottery. H.H.S.

Pottery making in a modern school. ANON. *Design*, **39** [9] 18–19 (1938).—Pottery making in the Norwood High School, Norwood, Ohio, is taught, in a comprehensive program, by Herbert H. Sanders whose aim is to introduce to the pupil the field of ceramics to explore rather than to give vocational training. The work includes manipulative skills, modeling, throwing, glazes, and firing. Illustrated. M.E.P.

Printing on glass. ANON. *Glaces & Verres*, No. 53, pp. 13–14 (1937).—Mechanical devices are described which permit the reproduction of drawings and similar graphical compositions by the printing process on either flat or hollow glass. R.W.D.

Relationship of art to industry. W. TURNBULL. *Jour. Textile Inst.*, **28** [12] P403–408 (1937).—T. discusses whether an industry gains most in artistic impulse from the works studio, the outside consulting studio, foreign studios or ateliers, or free-lance designers. The free-lance designer is the unpaid research worker of industry; the result of his greater freedom is sometimes a surprising freshness of outlook. H.H.S.

Sharp fire glazes. ANON. *Keram. Rundschau*, **45** [25] 273–75; [26] 288–91; [27] 299–300 (1937).—Examples of glazes with and without lead are given and discussed, including majolica glazes and underglaze paints. The reduction process is dealt with in detail. F.E.V.

Six centuries of painting in Antioch floors. ANON. *Science News Letter*, **33** [5] 77 (1938).—A complete history of painting from the 1st to 6th Century A.D. has been discovered through excavation of a unique series of mosaic floors. The mosaics are copies of early masterpieces, long since destroyed, executed with remarkable craftsmanship in variegated bits of limestone, terra cotta, and glass. P.G.H.

Stoneware pottery. D. BILLINGTON. *Pottery & Glass Record*, **20** [3] 74 (1938).—The first makers of salt-glazed stoneware in Staffordshire sought harder and whiter bodies than the local clays could produce. They required ware to compete with the tin-glazed delftware and with the mysterious ware just being introduced from China. Clays from Devonshire, including china clay and calcined flint, were gradually introduced, methods of manufacture were changed to suit the less plastic material, fat plastic shapes were replaced by molded patterns, and throwing fell back on turning and exchanged plasticity for thinness and "elegance." The potters gradually forgot how to pull a handle from a piece of soft clay, and many influences in the early part of the 18th Century tended to divert English pottery from its native tradition. The origin of the elaborate system of molding eventually used is not known; it was probably due to an increasing interest by wealthy people in pewter and silverware and to their desire for ornate decoration. Many pieces of stoneware pottery are "unclaylike" but otherwise beautiful. Today there is a return to thrown shapes and a new national style is gradually emerging. A.B.S.

Waugh's designs for Steuben glass. HELEN COMSTOCK. *Connoisseur*, **97** [413] 42 (1936).—See "Steuben —," *Ceram. Abs.*, **15** [4] 114 (1936). M.E.P.

Worcester pastille burners with English views. HELEN COMSTOCK. *Connoisseur*, **101** [439] 147 (1938).—C. describes a pair of pastille burners at St. James's Galleries made of Worcester porcelain in lavender and gold with molded decoration and scenic panels. These have been partially identified. A brief note is given on landscape decorations of Empire shapes by the artists of the Flight and Barr and the Chamberlain factories. M.E.P.

BOOKS

Glazed Tile from a Palace of Rameses II at Kantir. WILLIAM C. HAYES. Metropolitan Museum of Art. 46 pp., 13 plates. Price $2.00. Reviewed in *Science News Letter*, **32** [850] 64 (1937).—H. gives a report on the decorations of a palace believed to be that mentioned in Bible stories of Israelite encounters with Pharaoh. The palace ruins have not yet been identified, but finds from Kantir show that it was frequented by nearly all rulers throughout the Rameside period. P.G.H.

Handbook of Northern Arizona Pottery Ware. HAROLD SELLERS COLTON AND LYNDON LANE HARGRAVE. Northern Arizona Society of Science and Art. 267 pp. Price $4.00. Reviewed in *Science News Letter*, **33** [3] 48 (1938).—Types and where the type site occurs are described, and methods of studying potsherds and identifying them are explained. The book is valuable as a reference book for students of Southwestern pottery. P.G.H.

Mediaeval English Pavingtiles. LOYD HABERLY. Published by Basil Blackwell, Oxford, 1937. Printed at the Shakespeare Head Press Saint Aldates. 350 illustrations. Price £4 4s net. Limited to 400 copies. Reviewed in *Times Lit. Supp.*, **36** [1871] 941 (1937).—This is the first substantial work on the rich and vivacious craft of the medieval English picture-tile makers. Its large drawings will appeal to all students of medieval art and design. The archeologist will find in it a well-documented history of the origin, development, and decline of tile making, a full and exact illustrated survey of all decorated tile now surviving within 15 miles of Oxford, and a complete bibliography of other recorded picture tile. Its account of the use by 13th-Century tile makers of almost all the implements of the printer, including presses and fonts of small wood-letter type, is a new and highly important contribution to the history of printing; the description of H.'s practical experience in molding patterned tile and firing them in a reconstructed medieval kiln will enable the architect and potter to revive this lost craft in its old splendor. His unrivalled knowledge of medieval floor tile has enabled him to write learnedly yet lightly of a craft that, though humble, was always gay. The book is beautifully printed. H.H.S.

Stained and painted glass in England. CHRISTOPHER WOODFORDE. Society for Promotion of Christian Knowl-

edge, London, 1937. 40 pp. Price 6d. Reviewed in *Times Lit. Supp.*, **36** [1871] 948 (1937). H.H.S.

Younge Site: Archeological Record from Michigan. EMERSON F. GREENMAN. Univ. of Michigan Press. 172 pp. Price $2.25. Reviewed in *Science News Letter*, **33** [3] 48 (1938).—G. describes the excavation of a site containing remains of two pre-Columbian groups. The site includes enclosures, burials, and a variety of stone and pottery objects. P.G.H.

PATENTS

Decoration of ceramic products, glass, enameled iron, etc. L. ALLEN, N. W. WHITE, E. R. BOX, AND JOHNSON, MATTHEY, & Co., LTD. Brit. 480,660, March 9, 1938 (Oct. 18, 1937).

Designs for:

Ashtray. R. A. KELLY (United States Glass Co.). U. S. 109,218, April 12, 1938 (Jan. 31, 1938).

Bobêche. R. A. KELLY (United States Glass Co.). U. S. 109,219, April 12, 1938 (Jan. 31, 1938).

Bottle. R. A. KELLY (United States Glass Co.). U. S. 109,220, April 12, 1938 (Jan. 31, 1938). P. G. LLOYD (Carr-Lowrey Glass Co.). U. S. 109,021, March 29, 1938 (June 29, 1936).

Console bowl. R. A. KELLY (United States Glass Co.). U. S. 109,275, April 12, 1938 (Nov. 11, 1937).

Decanter. R. R. KOSTELLOW (United States Glass Co.). U. S. 109,221, April 12, 1938 (Feb. 5, 1938).

Glass building block. WILLARD PERKINS. U. S. 109,025, March 29, 1938 (March 16, 1937).

Goblet. R. R. KOSTELLOW (United States Glass Co.). U. S. 108,949, March 22, 1938 (Jan. 22, 1938); U. S. 108,950 to 108,952, March 22, 1938 (Jan. 28, 1938); U. S. 108,953 to 108,956, March 22, 1938 (Jan. 29, 1938).

Salad bowl. R. A. KELLY (United States Glass Co.). U. S. 109,276, April 12, 1938 (Nov. 11, 1937).

Siphon head. E. W. FUERST (Owens-Illinois Glass Co.). U. S. 109,241 to 109,245, April 12, 1938 (July 10, 1937). L. D. SOUBIER (Owens-Illinois Glass Co.). U. S. 109,254 to 109,256, April 12, 1938 (July 10, 1937).

Tumbler. R. A. KELLY (United States Glass Co.). U. S. 108,957, March 22, 1938 (Jan. 31, 1938). E. G. REDMAN. U. S. 108,964, March 22, 1938 (Sept. 11, 1936).

Method of applying a decalcomania. J. F. MCNUTT (American Decal Corp.). U. S. 2,111,897, March 22, 1938 (Nov. 16, 1935). The method of applying a decalcomania to an object having a vitreous surface consists in applying to such surface a collodion film having a design thereon containing a pigment and a material that will readily fuse with the surface to be decorated, firing the object by heating it first at a sufficiently low temperature and at a sufficiently low rate of increase in temperature to cause the film to be consumed and the design to become attached to the surface without injury to the design, and then heating it at a sufficiently high temperature to thoroughly fuse the design with the surface.

Stenciling apparatus. T. H. SLOAN (Simplex Engineering Co.). U. S. 2,113,413, April 5, 1938 (July 10, 1936).

Cements

Artificial breccia-like marble, "akarkhite." A. A. MAMUROVSKIĬ AND M. P. ELINZON. *Stroitel. Materialy*, **1937**, No. 11, pp. 46–54.—The material is made from concrete based on white, alumina, or other kind of cement with the addition of pigments (especially iron oxides). P.B. & E.S.

Calculation of the raw-material mixture of Portland cement from two components. M. STRELKOV. *Tsement*, **5** [7] 24–30 (1937).—Formulas are given for determining the rational composition of clinkers obtainable from the given raw materials and the composition of raw materials to obtain a clinker of a given rational composition. In calculations from two materials the moduli and the rational composition of the region of possible clinkers change as a hyperbolic function. Changes in the ratio of two materials of the batch cause very little changes in tricalcium aluminate and none in brownmillerite. P.B. & E.S.

Cement constitution. K. KOYANAGI, S. KATOH, AND T. SUDOH. *Zement*, **26** [34] 531–39 (1937).—Five Portland cement clinkers of very different chemical composition were manufactured by the industrial process, ground, and separated in parts of different specific gravity. The effect of granule size on specific weight is great. In every clinker the X-ray examination of the light fraction shows the characteristics of $3CaO \cdot SiO_2$. The presence of $\beta 2CaO \cdot SiO_2$, $3CaO \cdot Al_2O_3$, and $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ is discussed. Graphs and X-ray patterns are included. F.E.V.

Colored Portland cements. K. S. ZATZEPIN AND M. YA. BYCHKOV. *Tsement*, **5** [7] 30–34 (1937).—A light yellow color is obtained by introducing 0.1% of cobalt oxide into a batch with a low iron content. An increase to 0.5% gives a yellow coloring. The reflection coefficient of yellow cements varies from 40 to 66.9%; the purity of color varies from 38 to 48%. The addition of small amounts of cobalt oxide to the batch has no practical influence on the activity of the cements or on their setting rates. The pigment enters into the composition of clinker silicate minerals. In the English yellow Portland cements investigated, the pigment only forms a coating on the minerals. P.B. & E.S.

Determining the grade of cement with the aid of ultraviolet rays. N. D. CHERNYAVSKIĬ. *Tsement*, **5** [11] 35–42 (1937).—The phosphorescent coloring of cement is a function of its mineralogical composition, *i.e.*, of its activity. The photoelement reacts on the fluorescence of different grades and kinds of cement. The galvanometric values are lower, the higher the grade of cement. Cements of a low activity give a lighter fluorescent coloring and higher galvanometric values. P.B. & E.S.

Determining the quality of the clinker. W. ANSELM AND K. SCHINDLER. *Zement*, **26** [32] 502–507; [33] 515–18; [34] 546–51 (1937).—The quality of clinker in relation to the degree of firing is discussed. Many physical and technical properties of the cement are related to its specific weight. Every manufacturer should determine

a favorable weight which avoids underfiring and overfiring. In one instance, the best figure was 1.4 to 1.5; tensile strength, contraction, dielectric resistivity, etc., are considered. Graphs and tables are included. F.E.V.

Effect of different chemical compounds on the velocity of setting and mechanical strength of tamped cement. V. F. ZHURAVLEV AND B. M. SHAMSONOVA. *Tsement*, **5** [12] 14–20 (1937).—NaOH and KOH are the most energetic accelerators of the setting of cement mortars. A classification of the accelerating power of several chemical compounds is given. P.B. & E.S.

Formula for determining the output of multichamber cement mills. V. A. KIND, V. F. ZHURAVLEV, AND M. M. GORDON. *Tsement*, **5** [11] 21–28 (1937).—The following formula is suggested: $Q = KV$ kg./hr., where K = output for 1 m.³/hr. for the given type of mills and V = volume of the mill in m³. The value of the resistance of the material to grinding is very close to the crushing strength of the milled material, and the value of the latter can be substituted for it. The formula gives higher data than those guaranteed by firms, showing a certain reserve of output. It can also be used for mixtures of clinker with additions. P.B. & E.S.

Relation of dissociation temperature of limestone to the content of clay matter or magnesia. I. A. PEREDERIĬ. *Stroitel. Materialy*, **1937**, No. 11, pp. 55–61.—The dissociation temperature of natural limestone varies from 900° to 950° independent of the chemical composition. The temperature is lowered by admixtures of (*a*) clay matter ($SiO_2 + Al_2O_3 + Fe_2O_3$), (*b*) SiO_2 and Al_2O_3 separately, and (*c*) MgO. It can be determined accurately with the aid of the N. S. Kurnakov device. Mechanically and partly chemically bound water isolates at 350°; between 390° and 660° the dissociation of $MgCO_3$ takes place; the dissociation of $CaCO_3$ begins at about 720°. P.B. & E.S.

PATENTS

Apparatus for use in the manufacture of cement. J. H. HOFFMANN (G. Polysius Akt.-Ges.). U. S. 2,112,492, March 29, 1938 (Nov. 7, 1935).

Building material. H. E. PFFAF AND A. H. MCINTOSH. Can. 372,691, March 22, 1938 (Feb. 5, 1937). This process comprises intimately mixing magnesium oxide and magnesium chloride with the addition of a bond modifying agent of the nature of hydrous silicate of aluminum together with an inert filler. G.M.H.

Enamel

Acid-resisting enamels. A. DIETZEL. *Chem. App.*, **24**, 233–34 (1937).—D. discusses the types of enamel and their composition, properties, and field of application. The acid-resisting quality is considerably improved by addition of TiO_2. M.H.

Bathtubs annealed in huge atmosphere furnace. E. STEPHENSON, JR. *Ind. Heating*, **4** [8] 636–38 (1937).—S. describes the equipment for annealing sheet steels and the finished product in a nonoxidizing atmosphere of DX gas in a propane-heated radiant-tube furnace. M.H.

Behavior of enamels in contact with liquids at high temperatures and pressures. G. H. SPENCER-STRONG AND P. C. STUFFT. *Bull. Amer. Ceram. Soc.*, **17** [4] 170–73 (1938).

Black-edging problems. H. G. WOLFRAM. *Products Finishing*, **2** [2] 34–37 (1937).—After a general discussion of the details of black-edging, W. concludes that black-edge difficulties, such as chipping, crazing, hairlines, boiling through of the white, pits, copperheads, blisters, pinholes, and curling in the black edge itself, may be caused by (1) heavy application of the ground coat and (or) the black edge, (2) poor fit between ground coat and black edge with respect to softness and firing range, (3) excess alkali either in the ground coat or black edge, due to over addition in the mill or fast aging from an overheated condition, (4) wet spray, (5) thickness of ground coat and black edge, (6) high air pressure and close-up spraying, (7) underfiring, (8) poor set both of ground coat and black edge, and (9) excess aging even when the enamel is cool. H.K.R.

Bright annealing in the electric furnace. ULRICH SCHWEDLER. *Tech. Z. prakt. Metallbearbeit.*, **47**, 535–39 (1937); *Metals & Alloys*, **8** [12] MA736 (1937).—S. gives a review under the following headings: development of bright annealing, bright annealing of steel sheets, composition of protective gas, gas generator, description and operation of bright annealing furnace, bright annealing in boxes, and bright annealing of small parts on a mass-production scale. The following advantages of bright annealing in the electric furnace are particularly stressed: absence of complicated and expensive pickling, no chemical changes of surface of bright-annealed material, absolute insurance against carburization or decarburization, and maximum suitability for deep drawing purposes.

Coating capacity of enamel. HANS HADWIGER. *Glashütte*, **67** [49] 751–53 (1937); **68** [2] 22–25 (1938).—The coating capacity of enamel depends on (1) composition of the enamel frit, (2) additions to the mill, (3) additions of water, and (4) grinding fineness. The coating properties of enamel slip are determined by the rate of discharge (measured by two equal amounts by volume), the residue on coating, and the specific gravity. M.V.C.

Consideration of copperheads. L. K. SOSEY. *Bull. Amer. Ceram. Soc.*, **17** [4] 159–63 (1938).

Copperheading. H. C. BEASLEY. *Bull. Amer. Ceram. Soc.*, **17** [4] 163–66 (1938).

Copperheading of sheet-steel ground coats: a discussion. T. D. HARTSHORN. *Bull. Amer. Ceram. Soc.*, **17** [4] 166–68 (1938).

Difficulties in enameling cast iron. FERD. KELLER. *Glashütte*, **68** [4] 47–49 (1938).—Flaking of enamel was observed when using cast iron rich in sulfur. By changing the composition of the ground enamel, the impurities present on the cast-iron surface were decomposed and dissolved, and the enamel adhered well; 25 quartz, 5 soda, 1 saltpeter, and 0.5% adhering oxides were added to the ground enamel, while the mill additions were limited to 15% clay. Illustrated. M.V.C.

Electric cleaning and pickling of sheet iron prior to enameling. A. E. CHESTER, J. T. IRWIN, AND CLAYTON

ELLINGER. Presented at meeting of American Ceramic Society, Columbus, Ohio, March 29, 1936; abstracted in *Enamelist*, **13** [8] 19 (1936). E.J.V.

Enamel calculations. ALDINGER. *Glashütte*, **67** [48] 739–42 (1937).—While the computation of elasticity, resistance to pressure, and tensile strength of enamel is useless, it is essential to compute the composition of the melted enamel from the raw mixture of the enamel batch. A. explains the methods used; the coefficient of expansion of enamel can be computed by different methods from the composition of the enamel. M.V.C.

Enamel chipping: relationship of ground-coat adherence to the thickness and yield value of sheet steel. GEORGE SIROVY AND E. P. CZOLGOS. *Bull. Amer. Ceram. Soc.*, **17** [4] 168–70 (1938).

Enameled cast-iron distilling apparatus. A. DIETZEL. *Chem. App.*, **24**, 234–35 (1937).—D. discusses the advantages of enamel over other construction materials, especially in chemical respects. M.H.

Enamel as industrial material and its uses. RICHARD ALDINGER. *Chem.-Ztg.*, **61**, 813–15 (1937); abstracted in *Chem. Zentr.*, **1938, i**, 399.—A. gives a comprehensive review of the history, manufacture, raw materials, characteristics, properties, and fields of application of enamel. M.V.C.

Finishing Shelvador cabinets in new Crosley plant. F. W. VOGEL. *Products Finishing*, **2** [6] 7 (1938).—The equipment for cleaning, Bonderizing, spraying, and firing 1200 cabinets per day is illustrated. The need of cleanliness and care is stressed. H.K.R.

Frit solubility: II, Controlled variables of frit composition and their relation to enamel consistency. G. H. MCINTYRE AND R. E. BEVIS. *Jour. Amer. Ceram. Soc.*, **21** [5] 184–88 (1938); for Part I see *ibid.*, **19** [9] 249–52 (1936).

Handling waste acids from pickling operations. H. C. KLEIN. *Wire & Wire Prod.*, **12**, 701–706 (Nov., 1937); *Metals & Alloys*, **9** [3] MA170 (1938).—Pipe lines for removing waste acids are more often made of rubber-lined steel than of vitrified clay. Methods of obtaining leakless joints and general structural data are described.

Heat-resisting steel in the enamel industry. H. PETERSEN. *Chem. App.*, **24**, 235–37 (1937).—The technological and economical advantages of using heat-resisting steels for enameling are explained. M.H.

Heat technology in the enamel industry. H. PETERSEN. *Chem. App.*, **24**, 237–39 (1937).—Correct heat control in furnaces is important from the viewpoints of economy of the heating process and of the quality and uniformity of the finished product. Control methods are briefly discussed. M.H.

Leadless cast-iron frits. O. HOMMEL CO. *Ceram. Forum*, **3** [3] 2 (1936).—The use of leadless enamels in place of lead enamels on cast iron is increasing. They can now be fired at 1300° to 1340°F. Leadless enamels (1) reduce the health hazard of lead poisoning, (2) give truer, cleaner colors and are not susceptible to climatic conditions (such as sulfur content) as are lead enamels, and (3) effect savings through greater volume of enamel per pound of frit. H.E.S.

Metal cleaning and finishing. HERBERT R. SIMONDS. *Iron Age*, **141** [1] 500–504 (1938).—During 1937, progress was made mainly in commercial developments and in intensive application of equipment. Carbon tank linings have given great satisfaction; although their refractory properties have long been recognized, the use of carbon block to build a solid masonry wall is quite recent and has given rise to new techniques in bonding materials. E.H.McC.

Modern equipment facilitates enameling operations at United Stove Co. BARTLETT WEST. *Products Finishing*, **2** [1] 46–48, 50, 52–53 (1937).—A straight-line process including cleaning unit, Hydro-Filter spray booth, and firing ovens is described. It is claimed to be compact and well designed. 8 illustrations. H.K.R.

Pickling of steel; survey of recent work. T. P. HOAR. *Iron & Steel Ind.*, **10** [8] 340–44 (1937).—H. gives a review of theory and research rather than practical operation. Sulfuric acid and other baths, inhibitors, and electrolytic treatment are considered. 32 references. E.H.McC.

Porcelain enameling experiences and developments in Australia and the United States: I–II. F. M. BURT. *Products Finishing*, **2** [5] 7–16; [6] 24–35 (1938).—The revamping of an enameling plant is described in detail. Data are given showing how, even with simple equipment, savings can be made in running cost. Thirteen enamel formulas for ground, cover-coat, and cast-iron enamels are given with details of their application. H.K.R.

Shrinkage distortions and shrinkage stresses in welding. G. E. CLAUSSEN. *Welding Jour.* [N. Y.], **17** [3] 12–16 (1938).—C. discusses the origin and effects of distortion and stresses in welding. Empirical means of avoidance now in force may give way to design anticipation of warpage and stresses, due to accumulating knowledge on the subject. W.H.B.

Soda ash in iron casting. D. VORONIN. *Liteinoe Delo*, **8** [5–6] 37–39 (1937); *Metals & Alloys*, **9** [1] MA14 (1938).—An addition of about 0.5% soda ash in the ladle into which cupola Fe was poured greatly improved separation of the metal from slag, reduced porosity, and reduced sulfur content.

Vitreous enameling. A. J. G. SMITH. *Electrician*, **119**, 108 (1937).—Interesting results obtained in Germany with electric heating are as follows: (1) A furnace 4 ft. x 6 ft. 7 in. x 2 ft., using 100 kw., operating at 930°C with a 3-coat, 4-min. heating cycle, and using 920 kw.-hr./ton of material had no rejects as against 0.6% on its coal-fired predecessor; the all-inclusive cost per ton of material, including investment charges, was 43.5 Rm against 47.5 Rm for the coal furnace. (2) A small furnace with three chambers, each 2 ft. 7 in. x 2 ft. 7 in. x 1 ft., operating 20 min. at 835°C, using 50 kw. on a cast-iron 3-coat dry process, uses 590 kw.-hr./ton with 0.6% rejects; this furnace costs 37.3 Rm/ton compared with a producer-gas furnace which it replaced costing 81.7 Rm per ton. H.K.R.

PATENTS

Clouded enamel production. IGNAZ KREIDL. Can. 372,855, March 29, 1938 (Aug. 4, 1937). G.M.H.

Enamels. I. G. FARBENIND. A.-G. AND EISENWERK KAISERSLAUTERN. Fr. 816,225, Aug. 3, 1937; *Chem. Abs.*, **32**, 1890 (1938).—An enamel having a high re-

sistance to variations of temperature in cast Fe and malleable Fe is obtained by adding fused silicic acid, *e.g.*, quartzose glass or quartzose material, to the enamels used.

Enamels. KARL NÖLLING. Ger. 653,230, Nov. 18, 1937; Cl. 48*c*. 2.01; *Chem. Abs.*, **32**, 1890 (1938).—Borax or H_3BO_3 ordinarily used in the manufacture of enamels is replaced entirely or almost entirely by a Sr-Ca-Mg borosilicate, suitably by a borosilicate containing SiO_2 30 to 60, CaO 3 to 12, MgO 3 to 12, SrO 3 to 12, and B_2O_3 3 to 25%. Examples are given.

Manufacturing a tub. C. J. RODMAN (Steel Sanitary Co.). U. S. 2,114,150, April 12, 1938 (July 14, 1936).

Glass

Adsorption of radium by glass. I. E. STARIK AND A. M. GUREVICH. *Trudy Gosudarst. Radievogo Inst.*, **3**, 241–55 (1937).—The adsorption of radium by glass depends greatly on the purity of the solution. Adsorption in dependence on the p_H value of the solution was studied. With increased acidity adsorption greatly diminishes. Alkaline solutions contain impurities, and the results are not comparable with those obtained with acid media. Adsorption of radium by glass is apparently a function of time. B. A. NIKITIN AND V. M. VDOVENKO. *Ibid.*, pp. 256–65; abstracted in *Chem. Zentr.*, **1938**, i, 846.—Adsorption of radium by glass in dependence on Ra^{++}-ionic concentration and on the p_H value of the solution was determined. The amount of adsorbed radium was determined by treating directly with a HNO_3 solution. The dependence of radium adsorption on the Ra^{++}-ionic concentration is linear. With increased p_H value adsorption increases; this increase is larger with concentrated solutions. M.V.C.

Advances in metal-glass seals. ANON. *Radio Eng.*, **16** [3] 14–15 (1936).—For a metal to effect a vacuum-tight seal with glass, two principal conditions must be fulfilled: (1) the expansion of the metal and glass must be substantially the same under the temperature ranges encountered in the formation of the seal and the use of the finished unit, and (2) the glass must "wet" the metal when applied to it at a suitable temperature. The requirements, manufacturing methods, and an expansion curve for Kovar metal (29 Ni, 17 Co, 0.2% Mn, and the remainder Fe) and No. 705 AJ (hard) glass from 25°C to 600°C are given. A table also shows that thermal expansion from 25°C to 470°C is 4.8×10^{-6} for tungsten metal, 5.7 for molybdenum metal, and 5.1×10^{-6} for Kovar metal. Suitable glasses of 3.9 and 4.6×10^{-6} are also given. Illustrated. L.E.T.

Behavior of oxygen-releasing compounds in glass in the melting and fining process. C. KÜHL, H. RUDOW, AND W. WEYL. *Glastech. Ber.*, **16** [2] 37–51 (1938).—A new procedure has been developed for studying glass phase formation in batches, using Na uranate as a fluorescence indicator. Fluorescence develops only when a glass phase is formed. The base glass batch used for study was a mixture of 1 mol. Na_2CO_3, 1 mol. $CaCO_3$, and 6 mol. SiO_2. Additions to the extent of 0.01 mol. to 0.5 mol. B_2O_3, Na_2HPO_4, $Ca_3(PO_4)_2$, Na_2SO_4, Na_3PO_4, and As_2O_3 formed the series studied. The indicator, Na uranate, was present to the extent of 0.1% in each case. CO_2 loss was used as a measure of the extent of the reaction between 600°C and 925°C. Samples were dry-pressed into pellets. As_2O_3 speeds reactions without lowering the temperature at which a glass phase appears. B_2O_3 does both. In a glass batch of 14.5 Na_2CO_3, 6.8 KNO_3, 17.1 $CaCO_3$, and 61.5% SiO_2, the nitrates and intermediately formed nitrites are completely decomposed on reaching 800°C. Thus with only nitrates present, there is nothing to hold oxygen in the molten glass to aid in fining. The situation is different with fining agents such as As_2O_3. The As_2O_5-As_2O_3 equilibrium in the simple soda-lime-silica batch was followed analytically from room temperature to 1400°C, showing how the As_2O_3 can oxidize in the melting range. The behavior of antimony, manganese, and chromium oxides was studied in a similar manner. 29 references. J.F.H.

Blast-furnace glass. A. C. JEBBENS. *Deut. Tech.*, **5**, 442–53 (Sept., 1937); abstracted in *Chem. Zentr.*, **1937**, ii, 3934.—J. discusses the technical and economic aspects and present-day knowledge of the manufacture of glass with blast-furnace slag. It is possible to produce colored glasses from light yellow to black and green and opal-like glass. M.V.C.

Chemical resistance of glass and its testing methods. W. TEPOHL. *Glashütte*, **67** [34] 525–27 (1937).—T. discusses the Mylius method (*Ceram. Abs.*, **6** [9] 378 (1927)) of determining glass weathering with iodesine, the Mylius boiling method with subsequent titration of water, the Weber and Sauer method of determining the resistance of glass to acid and alkaline solutions, and the spot sensitivity method for optical or heavy lead crystal glass. M.V.C.

Dependence of glass composition on furnace atmosphere. ANON. *Sprechsaal*, **70** [48] 603–604 (1937).—The SO_3 content of glass which is dependent on the furnace atmosphere must be taken into consideration in analytical control, as otherwise the values of analysis will not be comparable. M.V.C.

Dependence of reaction velocity in glass batches on the physical properties and chemical composition of the raw materials: III, Relative melting velocity of glass batches with hydrated and dehydrated borax. F. H. ZSCHACKE. *Glastech. Ber.*, **16** [1] 13–19 (1938).—In glassforming mixtures, dehydrated borax reacts more slowly. This is attributed to the wetting of the sand grains by the aqueous solution formed by the hydrate as it melts. For Parts I–II see *Ceram. Abs.*, **15** [7] 202 (1936). J.F.H.

Developments in glassmaking. A. LAMESCH. *Rev. Tech. Luxembourg.*, **29** [6] 271–75 (1937).—The easy fragility and brittleness of glass can be improved by the so-called "Vorspannungs" method by which preimposed stresses are set up in the glass which, under ordinary conditions, are in equilibrium in the normal state of the glass. These preimposed stresses are produced by heating the glass to a temperature close to the softening point and then quenching it in an air current, whereby the faster cooling outer layers solidify first, contract, and try to take the still deformable inner part along. The latter then solidifies also and will contract but contraction is prevented by the outer rigid layers so that tensile stresses are pro-

duced in the inner part while compressive stresses are exerted on the outer layers. Such glass has a much higher strength since under exterior load the interior stresses are first compensated before an actual load is exerted; it is less fragile, is less sensitive to temperature fluctuations, and is more resistant to wear. The glass can be metallized; the sprayed-on metal layers adhere very firmly to the surface even if the glass is heated to 150°C. Brick of such glass have been used in building. Another development is foam glass, a glass containing many tiny bubbles of 0.5 to 5 mm. It has a compressive strength of 40 to 45 kg./sq. cm. and is used in the form of brick, plates, etc., and as an insulating material. M.H.

Dilatometer for investigating glasses. A. METZ. *Glastech. Ber.*, **16** [1] 19–20 (1938).—A new photographically registering dilatometer manufactured by the Leitz Co. is described. J.F.H.

Early German-Bohemian glass factories and glassmakers. J. BLAU. *Glastech. Ber.*, **16** [1] 20–21 (1938). J.F.H.

Effect of additions on the speed of crystallization of quartz glass. F. A. KURLYANKIN. *Ogneupory*, **5** [8] 533–40 (1937).—Foreign materials present in quartz glass, especially alkaline and alkaline earth oxides, accelerate its rate of crystallization. Each addition lowers the crystallization temperature of quartz glass by a definite number of degrees; alkaline additions lower it by 400° to 450° and lime and magnesia, by 150° to 200°. Glass with additions of alumina and iron oxides begins to crystallize at the same temperature as pure quartz glass. The lowering of the temperature of incipient crystallization is produced by lowering the softening temperature of the glass. Even a small change (0.05 to 0.10%) in the oxide contents, such as calcium, magnesium, or sodium oxides, produces a considerable change in the rate of crystallization. Thus, sands containing more than 0.02 to 0.03% of such materials are unsuitable for the manufacture of quartz glass. M.V.C.

Electric furnaces in the glass industry. R. RUMLER. *Elektrowärme*, **8** [2] 47–49 (1938).—R. discusses the use of electric heat in the glass industry in Czechoslovakia and describes experiences with several types of furnaces for melting, treating, and color-firing. Melting furnaces have not yet given much practical success, although the consumption is only 3 to 4 kw-.hr./kg. of glass. Electric heat seems more promising for Pb glasses because of their lower melting points. M.H.

Etching solutions. ANON. *Chem. Industries*, **42** [2] 174 (1938).—Four glass frosting materials for application to every kind of glassware, a new development of Westinghouse, are as follows: (1) a glass etch solution which produces permanent white markings on glass, is very fluid, and can be applied with a rubber stamp; (2) a metal etch solution, for application by rubber stamp to brass, copper, and silver, which produces a permanent and pleasing black finish, drying rapidly in the air without heat; (3) acid glass frosting solution No. 2, an etching material in paste form, producing a fine-grained white satin frost on any type of glass in 10 to 15 sec., and (4) No. 1 safety frost solution for glass, also in paste form, producing a finish similar to that produced by No. 2 but requiring treatment of the glass for 5 or 6 min. to produce similar results; being less corrosive, fewer precautions need to be taken in its use. P.G.H.

Faults from oils and their prevention. E. FELSNER. *Keram. Rundschau*, **44** [29] 340–41 (1936). F.E.V.

Fired-in colors and their application in the lamp-manufacturing industry. T. ZIENER. *Glas & Apparat*, **17** [21] 187–89; [22] 197–200 (1936).—Z. discusses the problems of firing-in colors in thin articles, *e.g.*, lamps, ampoules, etc., particularly when made of Thuringia glass (lime-soda glass) with a low softening point, and describes methods of obtaining a firmly adhering coating. Examples are shown. M.H.

Five centuries of glass: II, Franz Ruhmann collection. WOLFGANG BORN. *Connoisseur*, **101** [439] 121–25 (1938).—Glass of the first part of the 18th Century is represented in this collection by a goblet with a lid, a splendid example of glass carving in a high relief that corresponded with the taste of the baroque. This required a thick clear crystal glass, invented in Silesia, which was not known until 1680 and whose secret consisted in admixing chalk with the frit. A ruby glass goblet, beautifully simple in form and decoration is an example of "Kunckel-Glass," so named for the famous alchemist who first manufactured it at Potsdam in the early 18th Century. The rococo appearing in 1755 in the Silesian glass industry, much later than in Western Europe, and introduced through the influence of porcelain is represented in this collection by three strangely shaped glass cups for sweetmeats, with upper edges drawn into a high bow like a galley ship, gilded, and carved with *chinoiseries*. Stippled engraving, a Dutch technique developed after 1890, is illustrated by a wine glass signed by D. Wolff of Utrecht. In 1799, J. J. Mildner made glasses with gold engraving encased between two layers of glass. The method of inserting reliefs of porcelain in crystal glass was invented in France about 1790 and its technique flourished until 1850. This method is illustrated with three examples by Desprez that have a silvery shine due to a small layer of air between the porcelain and the glass. Illustrated. For Part I see *Ceram. Abs.*, **17** [4] 137 (1938). M.E.P.

Formation of grained surfaces on pressed glassware. F. ROLL. *Glastech. Ber.*, **15** [11] 427–28 (1937).—The grained surfaces on many kinds of pressed ware depend on the quality of the cast-iron mold. In this type of defective pressed ware, the grained surface develops through a coarse phosphide network. The effect can be avoided by a fine pattern, which can be produced in high phosphorous cast iron by suitable precautions. J.F.H.

Glass building blocks—the future of glazing. G. SCHIEB. *Oesterr. Glaserztg.*, **3**, 13–17 (1938). J.F.H.

Glass novelties in European markets. HOUYET GERPINNES. *Nat. Glass Budget*, **52** [34] 10 (1936).—The Uro-Punktal glass, made by Zeiss, will probably be used extensively in the manufacture of goggles. Many glass novelties are appearing on the market such as electrically warmed glass for aquariums. Stained glass studios have many orders for modern memorials inspired by the late war. H.E.S.

Gold-ruby glasses: III. W. GANZENMÜLLER. *Glastech. Ber.*, **15** [11] 417–25 (1937).—The rapid development of chemistry in the 19th Century led to a new orientation in glassmelting technique and a renewed practical and

theoretical interest in gold-ruby glass. For Parts I–II see *Ceram. Abs.*, **17** [5] 179 (1938). J.F.H.

Great improvement in lamps for all purposes. ANON. *Nat. Glass Budget*, **52** [24] 14 (1936).—Incandescent lamps are being made in sizes all the way from a minute "grain of wheat" bulb, used for surgical instruments, up to the 50,000-watt behemoths for floodlights. Developments have been made in two directions. Filament incandescents are being improved and adapted to new applications. Nonfilament tube lamps have been devised in which the stream of electric current passes through the mercury or chemicals that produce new qualities of light. New outstanding filament lamps are (1) auto headlight bulbs with two bar-shaped filaments for brilliance straight ahead and to the side of the road; (2) street-lighting lamps with horizontal bar filaments that permit the use of small nonbreakable glass bulbs; (3) a 1000-watt general service lamp with a white glass bulb the size of a pint bottle; (4) ultra-violet sun lamps for health use; and (5) a new flashlight bulb of extremely small size. New outstanding nonfilament lamps are (1) a 250-watt mercury vapor lamp with a tubular bulb; (2) a sodium lamp seen on the highways; (3) a capillary lamp like a small hypodermic needle said to produce a brilliancy exceeding the intensity of the noonday sun; (4) a fluorescent tube lamp producing a wide range of colors due to different powdered chemicals; and (5) "Sterlight," a tube sheding a ray which kills bacteria. Much progress has also been made in the development of scientific study and reading lamps. General Electric, Westinghouse, and other licensees under G. E. patents produce about 90% of all the lamps of American manufacture. H.E.S.

History of German and neighboring glass factories: I. H. KÜHNERT. *Glastech. Ber.*, **16** [2] 61–66 (1938).—More recent investigations are described. J.F.H.

How Ford makes its glass: I–II. F. G. SCHWALBE. *Glass Ind.*, **18** [12] 403–408 (1937); **19** [1] 15–20 (1938). **III.** *Ibid.*, [2] 57–60.—After the glass is washed and inspected for defects it is cut into the most desired bracket size by the Ford continuous bracket cutting and measuring device. A swiveling template-type machine or a completely mechanized machine in which the cutting device travels around a stationary template is used for cutting the glass to shape. The safety glass is laminated in a straightline production, the glass sandwich being sealed together in carefully controlled autoclaves. The edges are then ground and sealed against moisture. See *Ceram. Abs.*, **16** [9] 271 (1937). E.J.V.

Invisible glass windows in Chrysler International Automobile Salon, New York. ANON. *Nat. Glass Budget*, **52** [29] 3, 7 (1936).—More than 1000 sq. ft. of curved glass have been installed. Through the curving of the glass, all light reflections are eliminated, giving the illusion that no glass separates the passer-by from the interior of the salon. H.E.S.

Jena glass at Leipzig Fair. ANON. *Food Manuf.*, **13** [1] 19 (1938).—Heat-proof Jena glass was used at Leipzig in a display known as the "glass kitchen" and the "glass table." The "kitchen" referred to utensils for frying, roasting, steaming, or baking and the "table" to plates, gravy boats, milk jugs, etc. H.H.S.

Luminescence and color excited by radium in zinc borate glasses which contain manganese. B. E. COHN AND S. C. LIND. *Jour. Phys. Chem.*, **42** [3] 441–52 (1938).—Luminescence produced by exposure to radium of zinc borate glasses containing manganese indicates that the ordinary rules governing activators are applicable. The optimum concentration of manganese is 0.05%. The exposure produces a change in visible color which reaches a maximum at approximately 0.5% manganese. The resulting violet tint is caused by greater relative absorption in the long wave-length region of the visible spectrum. The absorption in the ultra-violet region is closely related to the luminescence emitted when the specimens are heated, and the initial visible and ultra-violet transparencies are almost completely restored by prolonged heating at or above 300°C. C.J.P.

Manufacture of colored glass of the Schott GG-3 type for filtering light. V. V. VARGIN AND L. O. SARAPIN. *Optiko-Mekh. Prom.*, **7** [3] 9–14 (1937); abstracted in *Chem. Zentr.*, **1937, ii,** 4085–86.—The spectrum curve of B-Na glass (Schott GG-3) colored with CdS and Se is greatly affected by the Fe content of the glass. To obtain a steep spectrum curve, either the iron content must be lowered or the Cd content increased. Due to the fact that Cd silicate is colorless, the Cd surplus affects the curve very little. The color is chiefly determined by sulfide-S in the presence of a sufficient amount of Cd; the former must not exceed 0.018 to 0.022%. Se affects absorption; a technically usable glass can be produced without selenium. Because of a limited solubility of CdS and CdSe in glass, precipitations of black crystals may appear at too low melting temperatures. A greater part of Cd and S volatilizes during melting. Glass with a definitely steep curve of absorption can be obtained only with a definite regulation of the sulfide-S content and careful thermal treatment; at higher temperatures the limit of permeability is shifted to the red part of the spectrum. Partial or complete opalescence may appear when cooling in a large pot; the colloidal particles of pigments become largest at about 900°; to avoid opalescence, the glass should be heated to 1000° and rapidly cooled to 600°. Glass similar to the GG-3 type was produced with the addition of 1 kg. $CdCO_3$ and 0.005 kg. selenium for 100 kg. glass, at a temperature of 1400° and 1420° and after treatment at 660°. M.V.C.

Precision heat in electric lamp production. ANON. *Nat. Glass Budget*, **52** [32] 14 (1936).—On the average, 1 cu. ft. of manufactured gas or $^1/_2$ cu. ft. of natural gas is required to manufacture a standard incandescent Mazda lamp. The average radio tube requires 3 cu. ft. of manufactured gas or $2^1/_4$ cu. ft. of natural gas. A total of 640 million large and miniature incandescent lamps and 65 million radio tubes were made in the United States in 1934. These two industries together consumed 700 million cu. ft. of gas fuel, of which 540 million cu. ft. were manufactured. The remainder, 160 million cu. ft., was natural gas. Two general types of glass are used in the manufacture: (1) a soft glass which is used in more than 90% of the common lamps; this is of two kinds, a lead glass for the stems and a lime glass for the bulbs; and (2) a hard glass, known as Pyrex brand or a modification of it. Uniformity of the chemical and physical characteristics of the fuel is extremely important. H.E.S.

Pyrex brand glass vessels in quantitative boron determinations. P. LAGRANGE. *Documentation Sci.*, **5**, 108–109 (1936); abstracted in *Chem. Zentr.*, **1938, i**, 132.—Bohemian glass, being too fragile, is unsuitable for the quantitative determination of boron as boric acid methyl ester. When using Jena or Pyrex brand glass, the boron values obtained have to be adjusted because these glasses lose some of the boric acid contained by them. M.V.C.

Ruby formation on a worn-out refractory block. W. BÜSSEM AND W. WEYL. *Glastech. Ber.*, **16** [2] 57–60 (1938).—Ruby formation appears to result from a breakdown of sillimanite containing Cr_2O_3 in the presence of soda. The same result was produced with an activated Al_2O_3 containing Cr_2O_3 by heating to 1200°C for $^1/_2$ hr. J.F.H.

Semiquantitative chemical spectral analysis in the continuous and interrupted arc. W. ROLLWAGEN. *Glastech. Ber.*, **16** [1] 10–13 (1938).—A series of 9 glasses was subjected to spectrum analysis using both types of arcs. The quantitative chemical analyses of 7 of these glasses are available. The tabulated data show good agreement between the chemical analyses expressed as atomic per cent and values expressing relative intensity of spectral lines. The continuous arc is satisfactory for normal analyses. Where very small quantities of material are available or greatest sensitivity is necessary, the interrupted arc is indispensable. J.F.H.

Spectrum analyses and their use in the investigation of glasses and raw materials: (A) Fundamentals and procedures. W. GERLACH. *Glastech. Ber.*, **16** [1] 1–4 (1938). **(B) Examples of the use of spectrum analysis in glass technology.** A. DIETZEL. *Ibid.*, pp. 5–6. **(C) Use of the electric arc in glass analysis.** W. ROLLWAGEN AND E. SCHILZ. *Ibid.*, pp. 6–10.—It is frequently possible to analyze valuable samples in localized areas without destroying the sample. The spectra of two historically valuable glasses are given. J.F.H.

Suitability of profile glasses in window glazing. W. ARNDT. *Glastech. Ber.*, **15** [11] 428–32 (1937).—Weakly profiled glass, in relation to uniformity and strength of the illumination of a room, is in no way different from ordinary window glass. The double profiled glasses and prismatic glasses tested were shown to be an important improvement over ordinary window glass in lighting effect. J.F.H.

Testing the shaping capacity of silica mixes. S. L. GERMAN. *Tech.-SO*, No. 380, 7 pp. (1937); abstracted in *Referat. Silikatliteratur*, **4** [9] 4445 (1937).—The shaping capacity of silica mixes changes with the duration of working. It is assumed, therefore, that some mixes are worked too long a time, others too short a time. A method has been developed to determine the shaping capacity of silica mixes. It is based on the method of Doty for testing molding sand in foundries. See *Ceram. Abs.*, **17** [1] 28 (1938). M.V.C.

BOOK AND CIRCULAR

Mineral wool. J. R. THOENEN. *U. S. Bur. Mines Information Circ.*, No. 6984, 54 pp. Free. T. presents the results of a field survey of plants producing mineral wool in 1935. See *Ceram. Abs.*, **8** [10] 777 (1929). R.A.H.

Modern Glass Working and Laboratory Technique. M. C. NOKES. Chemical Publishing Co., New York. 153 pp. Price $3.00. Reviewed in *Science News Letter*, **33** [6] 95 (1938).—This British text on the tricks of the glass-blower's art should be available in every chemistry and physics department which can not afford its own glass-blower. P.G.H.

PATENTS

Apparatus for:

Charging leers for cooling glassware. UNITED GLASS BOTTLE MANUFACTURERS, LTD. Ger. 652,154, Oct. 28, 1937; Cl. 32*a*. 34; *Chem. Abs.*, **32**, 1888 (1938).—This corresponds to Brit. 441,546, Feb. 5, 1936.

Drawing glass fibers. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY (T. F. S. Atkinson, applicant in U. S.). Fr. 816,325, Aug. 5, 1937; *Chem. Abs.*, **32**, 1887 (1938).

Drawing sheet glass. N. V. HOLLANDSCHE MIJ. VOOR DE VERVAARDIGING VAN GLAS. Brit. 481,222, March 23, 1938 (Dec. 24, 1935).

Making glass sheets by drawing. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Fr. 815,431, July 12, 1937; *Chem. Abs.*, **32**, 1888 (1938).

Making glass sheets by vertical drawing. N. V. HOLLANDSCHE MIJ. VOOR DE VERVAARDIGING VAN GLAS. Fr. 815,714, July 21, 1937; *Chem. Abs.*, **32**, 1887 (1938).

Marking articles. DAVID DENELSBECK (Owens-Illinois Glass Co.). U. S. 2,113,576, April 12, 1938 (Aug. 22, 1935; renewed July 16, 1937).

Severing vitreous tubing or rods. BRITISH THOMSON-HOUSTON CO., LTD. Brit. 480,423, March 9, 1938 (July 29, 1936).

Vertically drawing glass sheets. N. V. HOLLANDSCHE MIJ. VOOR DE VERVAARDIGING VAN GLAS. Fr. 816,212, Aug. 3, 1937; *Chem. Abs.*, **32**, 1887 (1938).

Device for controlling the feed of charges of glass to a glassblowing machine. N. V. PHILIPS' GLOEILAMPENFABRIEKEN. Brit. 480,470, March 9, 1938 (Dec. 12, 1935).

Drawing sheet glass. GEORG KILIAN (Deutsche Tafelglas A.-G.). U. S. 2,111,860, March 22, 1938 (Dec. 14, 1935).

Dual leer loader. J. P. BENOIT (Owens-Illinois Glass Co.). U. S. 2,113,929, April 12, 1938 (Sept. 29, 1934).

Electrical furnace. BLAISE COUSTEIX (Soc. Anon. des Manufactures des Glaces & Produits Chimiques de St. Gobain, Chauny & Cirey). U. S. 2,104,555, Jan. 4, 1938 (Jan. 13, 1936). (8) A rotary electrical furnace comprises a substantially horizontal heating resistance, a substantially horizontal casing for the material to be treated, the casing surrounding the resistance and comprising an envelope consisting of a nonmagnetic conducting metal, another metallic envelope surrounding the first-mentioned envelope and conductively connected therewith, and means interconnecting the two envelopes; means conductively connecting one end of the resistance to a source of electrical energy, means conductively connecting the opposite end of the resistance with the adjacent end of the casing, means conductively connecting the other end of the casing with the source of electrical energy, and insulated

means engaging the casing for rotating it around the resistance.

Electrical heating means. HENRI GEORGE AND GASTON DELPECH (Soc. Anon. des Manufactures des Glaces & Produits Chimiques de St. Gobain, Chauny & Cirey). U. S. 2,104,557, Jan. 4, 1938 (Jan. 27, 1934; May 16, 1936). (3) In combination, a rotatable horizontally disposed container, a heating rod within the container, the rod having a threaded end portion, means firmly engaging the threaded end portion to support one end of the rod within the container, the means extending through an opening formed in the container and constituting a closure for the opening, a terminal adapted to be connected to a source of electrical energy and connected with the means, a carriage supporting the means, means for adjusting the height of the carriage, means freely supporting the other end of the rod within the container, another terminal adapted to be connected to the source of electrical energy and connected with the third-mentioned means, means rotatable along with the container and supporting the third-mentioned means, the fourth-mentioned means being movable relatively to the third-mentioned means, and resilient means carried by the fourth-mentioned means and pressing the third-mentioned means against the other end of the heating rod.

Fluorescent glass. GEORGES HERTZ. Fr. 812,990, May 21, 1937; *Chem. Abs.*, **32**, 1064 (1938).—Substances capable of emitting complementary radiations of the excitation spectrum are introduced in the form of a colloidal suspension into the mass of glass, while giving to the glass a crystalline structure such that the radiations hitting it undergo a modification of their wave-length during the whole time of the irradiation. Three examples of such glasses contain SiO_2 100, 100, 100; dolomite 10, 7, —; K_2CO_3 25, 15, 23; borax 5, —, 4; Na_2CO_3 5, 12.5, 6; boric acid 11.5, 5, 17; Li_2CO_3 2, —, 2; Mg phosphate 1.5, —, —; cryolite 6, 7, —; $SnCl_2$ 6, 6, 5; ZnO —, 20, —; fluorspar —, 4, 8; Na_2SO_4 —, —, 1.5; NaCl —, —, 4; and hydrated Al_2O_3 —, —, 10 parts.

Forming siliceous fibers, especially glass fibers. N. V. MIJ. TOT BEHEER EN EXPLOITATIE VAN OCTROOIEN. Brit. 482,085, April 6, 1938 (May 28, 1936).

Frosted glass and method of making. O. J. STEWART. U. S. 2,111,576, March 22, 1938 (May 24, 1935). A method of frosting glass comprises immersing the glass to be treated in a bath of molten lithium compound and maintaining the time of immersion sufficiently long to produce a frosting of the desired intensity.

Furnace for fusing and refining glass. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE SAINT-GOBAIN, CHAUNY & CIREY. Fr. 815,655, July 20, 1937; *Chem. Abs.*, **32**, 1889 (1938).—The molten glass is passed in a thin layer over a strongly heated vertical or inclined surface, so that the glass is freed from occluded air bubbles.

Glass. BRITISH THOMSON-HOUSTON CO., LTD. (General Electric Co.). Brit. 481,067, March 16, 1938 (May 19, 1937).

Glass article manufacture. OTTO FRITZE AND ALFRED RUTTENAUER (Canadian General Electric Co., Ltd.). Can. 372,738, March 29, 1938 (Feb. 27, 1935). G.M.H.

Glass article tempering apparatus. J. B. MITFORD (Pilkington Bros., Ltd.). Can. 372,665, March 22, 1938 (Dec. 31, 1935). G.M.H.

Glass article tempering method. W. W. SHAVER (Corning Glass Works). Can. 372,779, March 29, 1938 (July 7, 1936; in U. S., Sept. 24, 1935). G.M.H.

Glass batch. F. C. FLINT (Hazel-Atlas Glass Co.). U. S. 2,113,195, April 5, 1938 (March 6, 1936). A glass batch for colorless transparent container glass, etc., includes barium sulfate and a metallic reducing agent for the barium sulfate, the reducing agent consisting of a metal which will not influence the character of the colorless transparent container glass if used in excess of the amount required for complete reduction of the barium sulfate.

Glass-drawing tank. FRAZIER-SIMPLEX, INC. Brit. 480,506, March 9, 1938 (March 29, 1937).

Glass-feeding apparatus and method. W. A. MORTON (Hartford-Empire Co.). U. S. 2,113,963, April 12, 1938 (refiled from abandoned application Serial No. 272,755, April 25, 1928; May 24, 1933).

Glass insulators. CORNING GLASS WORKS. Fr. 816,644, Aug. 12, 1937; *Chem. Abs.*, **32**, 1889 (1938).—The insulators are made of glass tempered so that predetermined parts are under a greater compression than other parts.

Glass tempering method. H. R. LILLIE AND W. W. SHAVER (Corning Glass Works). Can. 372,035, Feb. 22, 1938 (Nov. 10, 1936; in U. S., Dec. 30, 1935). G.M.H.

Glass threads. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE SAINT-GOBAIN, CHAUNY & CIREY. Fr. 815,503, July 13, 1937; *Chem. Abs.*, **32**, 1887 (1938).—The construction of an orifice from the fusion furnace is described.

Glass vessel. H. R. LILLIE AND W. W. SHAVER (Corning Glass Works). Can. 372,034, Feb. 22, 1938 (July 7, 1936). G.M.H.

Glass vessel producing apparatus. JAKOB DICHTER. Can. 371,960, Feb. 15, 1938 (July 15, 1936). G.M.H.

Handle for glassware. WALTER VON NESSEN (A. H. Heisey & Co.). U. S. 2,114,260, April 12, 1938 (July 3, 1936).

Insulator. J. T. LITTLETON (Corning Glass Works). Can. 372,781, March 29, 1938 (Dec. 12, 1936; in U. S., Jan. 31, 1936). G.M.H.

Joining glass blocks. J. F. HYDE (Corning Glass Works). U. S. 2,112,241, March 29, 1938 (April 22, 1937).

Laminated or compounded safety glass and its manufacture. TUDOR SAFETY GLASS CO., LTD., C. T. PUGH, AND W. ASH. Brit. 482,170, April 6, 1938 (Nov. 26, 1937).

Laminated glass. ADOLF KÄMPFER. Can. 371,898, Feb. 15, 1938 (June 5, 1935); Can. 371,982, Feb. 15, 1938 (Sept. 14, 1935); Can. 371,983, Feb. 15, 1938 (Oct. 3, 1935). G.M.H.

Lens. H. R. MOULTON (American Optical Co.). Can. 372,141, March 1, 1938 (Oct. 26, 1936). G.M.H.

Machines for making glass bottles, etc. W. E. EVANS (O'Neill European Machine Co. of Montreal). Brit. 480,741, March 9, 1938 (Aug. 24, 1936).

Making lenses. E. J. REH (Bausch & Lomb Optical Co.). U. S. 2,112,659, March 29, 1938 (May 2, 1934).

Manufacture of fibers from glass, etc. A. E. EDWARDS (N. V. Mij. tot Beheer en Exploitatie van Octrooien). Brit. 481,690, March 30, 1938 (Feb. 8, 1937).

Manufacture of glass pipes. J. A. JOBLING & Co., LTD., AND E. J. JOBLING-PURSER. Brit. 482,266, April 6, 1938 (Nov. 5, 1937).

Manufacture of laminated glass. M. L. MACHT (E. I. du Pont de Nemours & Co.). U. S. 2,113,764, April 12, 1938 (July 18, 1936). LOUIS PAGGI (E. I. du Pont de Nemours & Co.). U. S. 2,113,767, April 12, 1938 (July 18, 1936).

Method and apparatus for feeding molten glass. F. L. O. WADSWORTH (Ball Bros. Co.). U. S. 2,113,956, April 12, 1938 (March 27, 1935).

Method and apparatus for forming siliceous fibers, especially glass fibers. N. V. MIJ. TOT BEHEER EN EXPLOITATIE VAN OCTROOIEN. Brit. 482,090, April 6, 1938 (July 24, 1936).

Method and apparatus for producing fibers from molten glass, etc. P. MODIGLIANI. Brit. 481,827, March 30, 1938 (Feb. 17, 1937).

Method and apparatus for working glass. L. D. SOUBIER (Owens-Illinois Glass Co.). U. S. 2,113,551, April 5, 1938 (Dec. 5, 1933).

Mineral wool. C. F. RAMSEYER (Chicago District Electric Generating Corp.). Can. 371,921, Feb. 15, 1938 (Jan. 7, 1937; in U. S., Nov. 2, 1936). G.M.H.

Ophthalmic lens. E. D. TILLYER (American Optical Co.). Can. 372,142, March 1, 1938 (March 3, 1937). Can. 372,143, March 1, 1938 (June 7, 1937). G.M.H.

Sealing electric conductors through quartz or hard glass. GENERAL ELECTRIC CO., LTD. (Patent Treuhand-Ges. für elektrische Glühlampen). Brit. 482,318, April 6, 1938 (Nov. 6, 1936).

Sealing laminated or compounded safety glass. TUDOR SAFETY GLASS CO., LTD., C. T. PUGH, AND W. ASH. Brit. 482,169, April 6, 1938 (March 3, 1937).

Sealing off the glass filling tubes of vessels filled to a pressure higher than atmospheric. GENERAL ELECTRIC CO., LTD. (Patent Treuhand-Ges. für elektrische Glühlampen). Brit. 480,984, March 16, 1938 (Dec. 23, 1936).

Spinning glass thread mats. CHANCE BROS. & CO., LTD., AND A. L. FORSTER. Brit. 481,286, March 23, 1938 (Aug. 8, 1936).

Stabilizing glass articles. CORNING GLASS WORKS. Fr. 815,376, July 10, 1937; *Chem. Abs.*, **32**, 1887 (1938).—Articles such as thermometers are maintained for a relatively short time at a temperature appreciably above the maximum temperature to which the article is exposed during service but not appreciably above the temperature of tension of the glass.

Tempered glass article. J. T. LITTLETON, H. R. LILLIE, AND W. W. SHAVER (Corning Glass Works). Can. 372,780, March 29, 1938 (Sept. 11, 1936; in U. S., Sept. 24, 1935). G.M.H.

Transparent building unit. D. E. GRAY AND D. E. GREGORY (Corning Glass Works). Can. 372,036, Feb. 22, 1938 (Jan. 27, 1937; in U. S., March 25, 1936). G.M.H.

Variegated glass sheets and processes and apparatus for their manufacture. H. A. FISHER. Brit. 481,148, March 16, 1938 (July 10, 1937).

Vitreous siliceous article production. J. A. HEANY. Can. 372,557, March 15, 1938 (Feb. 25, 1937). A method of producing vitreous translucent nonporous silica articles of high strength and density comprises forming and firing an article composed of a reactive, readily vitrifying, finely divided silica obtained by the decomposition of gaseous silicon compounds, the firing being carried out at a temperature above 1200 °C but below the fusion point of silica. G.M.H.

Structural Clay Products

Base-course design. P. E. MASHETER. *Proc. Nat. Paving Brick Assn.*, **1937**, pp. 62–65.—M. discusses base-course design as studied by the Ohio Highway Department and points out that very often it is the failure of the base course which causes the ultimate failure of the pavement. Subsoil conditions vitally influence the base-course construction and should be thoroughly understood before any construction recommendations are formulated. Reinforcement of the base course with steel matting has been found of value in strengthening the course and also in holding the fractured slabs together. **Discussion.** C. D. WILLMAN. *Ibid.*, pp. 66–68. M.C.S.

Brick in street reconstruction, St. Paul, Minn. GEORGE M. SHEPARD. *Proc. Nat. Paving Brick Assn.*, **1937**, pp. 17–20. M.C.S.

Cast paving blocks from blast-furnace slags of the Nizhne-Tagil iron and steel works. A. I. ZHILIN AND L. P. IGNAT'EVA. *Stroitel. Materialy*, **1937**, No. 12, pp. 16–20. P.B. & E.S.

Change of physical properties of lime-silica rock by sodium silicate solutions. I. YA. SLOBOD'YANIK AND L. A. MELENEVSKIĬ. *Stroitel. Materialy*, **1937**, No. 7, pp. 46–49.—The impregnation of diatomite rock by Na silicate solutions with or without a subsequent treatment with 2% HCl improves its properties as a building material and makes it suitable for decorative purposes. Surface treatment has less effect. Impregnation darkens the surface of the rock. Special pigments can be used on the impregnated rock. P.B. & E.S.

Current research in brick as a paving material. G. F. SCHLESINGER. *Roads & Streets*, **80** [1] 43–46 (1937).—Twenty-one fillers comprising cement, asphalt, pitch, and plasticized sulfur are being tested in short stretches of highway. Four of these have been selected for large-scale tests. The temperature gradient between the base and brick top is being investigated under actual service conditions. The laying of brick is being varied in test stretches of road to determine the advantages and disadvantages of each type. Brick are being further improved by devising more accurate methods of controlling and checking the manufacturing process. P.G.H.

Determination of efflorescence on ceramic products. JOSEF MATĚJKA. *Tonind.-Ztg.*, **61** [74] 830–31 (1937).—The property responsible for all efflorescence is the capillarity or water permeability. For a test, the specimen is put upright in water 1 cm. deep, and the increase in the height to which the water rises and the increase in weight are checked at regular intervals. After 7 days, the scum formed is carefully scraped off and analyzed. Sulfates are most detrimental; nitrates and chlorides are less so and

less frequent. Carbonates are detrimental only to the appearance. The worst sulfates are $MgSO_4$ and Na_2SO_4. To test for the tendency to form secondary scum, a 1% solution of $MgSO_4$ and Na_2SO_4 should be used instead of water. See *Ceram. Abs.*, **15** [11] 337 (1936). W.K.

European paving brick. G. A. Bole. *Proc. Nat. Paving Brick Assn.*, **1937**, pp. 42–43.—France and Germany have very few brick pavements; Holland, however, uses brick quite extensively. M.C.S.

Hocking County experimental road. W. W. Duecker. *Proc. Nat. Paving Brick Assn.*, **1937**, pp. 60–61.—D. presents further information concerning the plasticized sulfur-type filler. The two grades of prime importance at present are Type A, consisting of 60 sulfur, 30 graded aggregate, and 10% plasticizer known as Thiokol; and Type B, consisting of a mixture of sulfur and asphalt. Both of these products have proved highly satisfactory from the standpoints of application and limited service tests. See *Bull. Amer. Ceram. Soc.*, **16** [11] 435–38 (1937). M.C.S.

Longitudinal brick project. Boyd V. Wright. *Proc. Nat. Paving Brick Assn.*, **1937**, pp. 21–27.—Paving brick were laid in the pavement longitudinally. Adverse weather conditions at the time the base course was laid and when the brick were laid, in addition to several inadequacies in the specifications for laying such a pavement, were contributing factors in the failure of this highway to meet with complete satisfaction. **Discussion.** V. N. Holderman. *Ibid.*, pp. 28–29. M.C.S.

Nonplastic materials of the heavy clay industry. Anon. *Tonind.-Ztg.*, **61** [52] 581 (1937).—The advantages and disadvantages of inorganic and organic nonplastic materials used in the manufacture of brick are briefly discussed with regard to forming, drying, firing, and shipping. W.K.

Paving-brick specifications. F. H. Jackson. *Proc. Nat. Paving Brick Assn.*, **1937**, pp. 51–53.—J. discusses the failure of the present rattler test to indicate positively the true characteristics of all pavers and to indicate their resistance to cracking and breaking in the street. M.C.S.

Paving brick in stadium construction. J. Davis Wilson. *Proc. Nat. Paving Brick Assn.*, **1937**, pp. 30–33.—In this project, pleasing and satisfactory results were produced through the use of a great number of second and inferior grade pavers. M.C.S.

Rattler test from the standpoint of broken brick. R. R. Litehiser. *Proc. Nat. Paving Brick Assn.*, **1937**, pp. 54–56.—L. discusses the relationship between the rattler tests and satisfactory service. He points out that brick showing high rattler losses and low flexure strength give poor service and crack badly in the pavement. M.C.S.

Reconstructing brick-paved Stewart Avenue in Ithaca, N. Y. Harry W. Eustance. *Proc. Nat. Paving Brick Assn.*, **1937**, pp. 11–16. M.C.S.

Reconstruction with brick in Toledo. George N. Schoonmaker. *Proc. Nat. Paving Brick Assn.*, **1937**, pp. 7–10. M.C.S.

Report of the Research Bureau to Thirty-First Annual Meeting of the National Paving Brick Assn. H. Z. Schofield. *Proc. Nat. Paving Brick Assn.*, **1937**, pp. 44–50; See *Bull. Amer. Ceram. Soc.*, **16** [11] 435–38 (1937); *Ceram. Abs.*, **17** [4] 142 (1938). M.C.S.

Suitability of Pfahl quartz for manufacturing silica brick. R. König and L. Stuckert. *Sprechsaal*, **70** [42] 527–29; [43] 541–43; [44] 556–57; [45] 565–68 (1937).—Without admixture, Pfahl quartz is not sufficiently transformed on firing; sodium chloride is the best admixture. An increase in the amount of admixtures has a certain limit, after which they no longer promote transformation. An increase in the firing temperature and a longer firing time greatly promote transformation. Increased grain coarseness hampers transformation and requires longer firing time. Chilling of quartz promotes transformation. Brick samples containing 2% sodium chloride and 2% lime (added in the form of milk of lime) showed a specific gravity of 2.324 to 2.328 and a resistance to pressure of 150 to 390 kg./sq. cm. when cold. M.V.C.

Twenty years of the brick industry of the U.S.S.R. N. G. Chibunovskiĭ. *Stroitel. Materialy*, **1937**, No. 11, pp. 6–14. P.B. & E.S.

COMMUNICATION

Thermal expansion of paving tile in relation to the crystallographic transformation of quartz. F. W. Hisschemöller. *Communication of the Laboratory of N. N. Vlamovenstraatklinker*, **1935**, Nov., 8 pp.; abstracted in *Referat. Silikatliteratur*, **3** [5] 2865 (1936).—Samples manufactured from powdered rock materials and clay showed no cristobalite effect on heating. See *Ceram. Abs.*, **16** [2] 63 (1937). M.V.C.

PATENTS

Brick, building blocks, etc. H. Dean of Stoneware (1928), Ltd., and J. F. Cubbon. Brit. 481,113, March 16, 1938 (Sept. 4, 1936).

Brick for the construction of built-up hollow structures such as cylindrical silos, storage bins, tanks, etc. O. D. Henry. Brit. 481,604, March 30, 1938 (Sept. 16, 1936).

Building block and tile. Rudolph Kalkusch. Can. 372,705, March 22, 1938 (Feb. 25, 1937); See *Ceram. Abs.*, **16** [1] 17 (1937). G.M.H.

Flashing block. W. F. Cox. U. S. 2,112,332, March 29, 1938 (Oct. 22, 1936).

Sound absorbing and heat insulating unit. J. W. Morgan (Zonolite Co. of Montana). Can. 372,217, March 1, 1938 (April 12, 1937). G.M.H.

Refractories

Air-jacketed heat treatment and forging furnaces. David Brownlie. *Iron & Steel Ind.*, **10** [13] 587–88 (1937).—New Liptak furnaces are built with suspended air-cooled refractory walls and suspended arches attached to a steel frame, with combustion air supplied by a self-contained motor-driven fan (with or without recuperators), and use solid, liquid, or gaseous fuel. A typical solid furnace wall ($16^1/_2$ in. thick) stores 41,250 B.t.u./sq. ft. after soaking, while the suspended wall (9 in. thick, with 6-in. air space and 3-in. insulating casing) stores only 26,350 B.t.u. The maximum heat loss per hr. from the solid wall when soaked is 650 B.t.u./sq. ft., and from the suspended wall it is only 250 B.t.u. E.H.McC.

Blast-furnace bottom. I. Astakhov, I. Nekrassov,

AND G. GRECHKO. *Teoriya & Prakt. Met.*, **9** [3] 17–20 (1937); *Metals & Alloys*, **8** [12] MA744 (1937).—Bottoms are to be made of cast Fe blocks on the top of which a chromite lining is placed.

Cracking process. G. EGLOFF AND E. F. NELSON. *Trans. Amer. Inst. Chem. Engrs.*, **32**, 221–70 (1936).—The service requirements in cracking heaters have contributed greatly to better refractories and the development of special refractories. Modern cracking conditions make it necessary to cool the heaters and bring them up to operating temperatures very quickly. This imposes high strains on the refractories and tends to make them spall. A medium-priced nonspalling brick has been developed to answer this need. Oil fuel used in the refineries has also necessitated a refractory to resist considerable slagging action. Refractories used in "cracking furnaces" possess the following properties, depending upon the grade of refractory used: P.C.E. 28 to 34; alumina content 38 to 46%; basic oxides 3 to 4.5%; shrinkage or expansion at 1600°C, 1.0 to 1.5%; compression on load of 25 lb./sq. in. for 4½ hr., 2 to 7%; loss on spalling (Amer. Refrac. Inst. Spalling Test after two cycles) (not more than) 5 to 15%. H.E.S.

Density of grog in relation to its granulometric composition. E. K. KELER. *Ogneupory*, **5** [8] 530–33 (1937).—The effect of grinding fineness on grog for refractories used in glassmelting is discussed. M.V.C.

Durability of refractories. J. F. HYSLOP. *Foundry Trade Jour.*, **55**, 179, 182 (1936); *Metal Treatment*, **2** [6] 86–88 (1936); *Iron & Coal Trades Rev.*, **133** [3574] 332 (1936).—Four groups of refractories are distinguished; they are, in the order of increasing basicity, (1) acid-SiO_2, $3Al_2O_3{\cdot}2SiO_2$, Al_2O_3, $SiO_2{\cdot}ZrO_2$, SiC-silica, clay, sillimanite, mullite, corundum, zircon, and silicon carbide; (2) spinel-$R''O{\cdot}R'''_2O_3$-magnesia spinel, chrome; (3) orthosilicate-$2R''O{\cdot}SiO_2$-olivine, forsterite; and (4) basic-$R''O$-magnesite, dolomite. A refractory is, in most cases, a collection of mineral crystals set in a glassy bond, their physical and chemical properties depending on the nature and amount of the crystalline and glassy phases. All refractories have definite limitations even under well-controlled conditions. Silica is good under load but poor under thermal shock. Corundum is good both under load and thermal shock. Sillimanite is also good under load and thermal shock. Chrome is poor under load and thermal shock. Spinel is good under both and magnesite is poor under both. Spalling resistance of silica can hardly be improved due to the transformation from cristobalite to tridymite taking place between 200° and 300°C. The effect of atmosphere is discussed. M.H.

Effect of coke gas and water steam on refractories of coke chambers at high temperature. G. O. DESCHALIT. *Koks & Khim.*, **7** [8] 35–36 (1937); abstracted in *Chem. Zentr.*, **1938, i**, 402–403.—The refractories used were (*a*) grog, (*b*) silica, (*c*) semi-acid, and (*d*) quartz brick whose compositions were: (*a*) 54.18 SiO_2, 42.7 Al_2O_3, 0.86 Fe_2O_3, 0.75 CaO, 0.26% MgO; (*b*) 96.16 SiO_2, 0.29 Al_2O_3, 0.74 Fe_2O_3, 3.4 CaO, 0.03% MgO; (*c*) 59.18 SiO_2, 33.14 Al_2O_3, 2.06 Fe_2O_3, 1.36 CaO, 1.37% MgO; and (*d*) 99.5 SiO_2. Thermal resistance was determined by calcining at 850° and chilling in water. Brick *a* and *b* were not resistant, and brick *c* had an average value. Resistance to steam was tested on samples heated to 1000° for 8 hr. Brick *a* and *d* were not affected by steam. A mixture of steam and coke gas was most effective on brick *b* at 900° and much less on brick *c* and *d*. M.V.C.

Fireclay ladle sleeves. RAYMOND A. HEINDL AND GEORGE J. COOKE. *Jour. Research Nat. Bur. Standards*, **20** [3] 411–18 (1938); R.P. 1084. Price 5¢.—A study was undertaken of eight brands of sleeves made by seven manufacturers. Certain properties of these sleeves were determined in the laboratory, and records were obtained of the sleeves in steel-foundry service. The results obtained in the laboratory are coördinated with the service results obtained in the foundry, and the following conclusions appear justified: (1) The temperature of softening of the sleeves in all but two cases was below the temperature of the molten steel surrounding them; in the extreme case the metal was hotter by approximately 115°C. (2) Excessive cutting and pitting during the casting of heats (average time 18 min., maximum about 30 min.) were noted in many sleeves of low refractoriness. (3) The average porosity of all brands of sleeves ranged from 11.4 to 21.8%, although one brand showed a range in porosity from 9.2 to 20.6% for the different sleeves. Those of lowest porosity in this brand gave serious trouble as a result of spalling and cracking. (4) The range in Young's modulus was from 1,842,000 to 4,964,000 lb./in.^{2} The modulus of rupture ranged from 1020 to 2310 lb./in.^{2}, and the extensibility ranged from 0.365 to 0.644%. The highest value for Young's modulus accompanied by the lowest value for extensibility was found in the brand of sleeves which caused much trouble due to spalling and cracking in foundry service. (5) The silica content ranged from 55.42 to 65.99%. Service results on the sleeves in contact with acid open-hearth slags were satisfactory in all of the limited number of heats observed. (6) The total linear thermal expansions ranged from 0.545 to 0.670%. All curves showed some inflection due to crystalline silica inversions in either the 100° to 200°C or 500° to 600°C temperature ranges, although the inflection was small in some cases. (7) The brand of sleeves which gave the most satisfactory results in service was very refractory, had fairly high porosity, a fairly uniform and not high expansivity, and a moderately high extensibility. (8) A great deal of variation in the properties and service results was noted in different sleeves of some of the brands, indicating lack of uniformity in the product. (9) There was a sharp dividing line in the degree of refractoriness between the two brands of sleeves of highest refractoriness and the remainder of the brands. R.A.H.

Foreign refractory materials for coke ovens. G. V. KUKOLEV. *Koks & Khim.*, **7** [8] 37–40 (1937); abstracted in *Chem. Zentr.*, **1938, i**, 402.—"Gitempite," a refractory cement, consists of coarse-grained quartz, grog, clay, water glass, and water. It is slightly resistant to temperature and softens when subjected to temperatures prevailing in coke ovens owing to high alkalinity and the use of fired grog. Cement *A* is a mixture of quartz, refractory clay, and water glass; cement *B* is a mixture of grog, refractory clay, and Na-aluminate solution. M.V.C.

Heat transmission. T. B. DREW, H. C. HOTTEL, AND W. H. MCADAMS. *Trans. Amer. Inst. Chem. Engrs.*, **32**, 271–305 (1936).—The fundamental problems underlying

conduction, convection, and radiation are discussed, and many applications are presented. H.E.S.

Heat treating refractories. T. W. LIPPERT. *Iron Age*, **141** [1] 424–26, 428, 430, 432 (1938).—In a review of progress during 1937, L. discusses new alloys, controlled atmospheres, and developments in heat treating in general but gives nothing on refractories. E.H.McC.

Hydraulic refractory bodies. A. I. ROĬZEN. *Ogneupory*, **5** [6] 373–81 (1937).—Attempts to manufacture refractory concrete showed that aluminous cement may be used as a bond, while chromite, bauxite, corundum, grog, etc., may be used as filling agents. The products obtained have high mechanical strength and thermal stability and constant volume at high temperatures. M.V.C.

Manufacture and properties of refractory products. MARCEL LÉPINGLE. *Bull. Soc. Roy. Belge Ing. Ind.*, **1937**, 665–85; *Chem. Abs.*, **32**, 741 (1938); see "Actual—," *Ceram. Abs.*, **17** [5] 185 (1938).

Measurement of thermal conductivity of insulating materials. "Touchau" (contact) method. P. VERNOTTE. *Chaleur & Ind.*, **18**, 331–39 (1937); *Brit. Chem. & Phys. Abs.-B*, **57** [2] 113 (1938).—Mathematical.

Methods of testing the mechanical strength of silicate brick. A. S. RAZORENOV. *Stroitel. Materialy*, **1937**, No. 12, pp. 5–11. P.B. & E.S.

Porous magnesite products. P. S. MAMYKIN AND S. G. ZLATKIN. *Ogneupory*, **5** [8] 541–44 (1937).—On the basis of laboratory experiments with lightweight, porous magnesite products (manufactured with additions of coke), it was found that such brick may be successfully used in some parts of open-hearth furnaces. M.V.C.

Radiation properties of several silicoalumina refractories. A. BARITEL. *Chaleur & Ind.*, No. 215, pp. 237–45 (1938).—The measurement of the radiation properties of refractory brick at temperatures from 950° to 1200°C is made in a graphite furnace using a carbon arc. Temperature readings are taken with an optical pyrometer of the disappearing-filament type, sighted on holes in the specimen of varied depths and diameters. The true temperature of the surface of the specimen is obtained by extrapolation to black-body conditions. Radiation is measured directly by means of a radiation pyrometer. Calibration curves and a discussion of the accuracy of the measurements are given. V.D.F.

Rapidly transforming quartzites. A. M. TRAKHTENBERG. *Ogneupory*, **5** [7] 436–40 (1937).—South Russian quartzites rich in silica were tested with regard to their chemical properties and structure. They have a very dense structure and are composed of 60% cement-like mass and up to 35% of quartz grains having a diameter larger than 0.1 mm. These quartzites do not disintegrate on firing. M.V.C.

Refractories and their application. W. F. ROCHOW. *Trans. Amer. Inst. Chem. Engrs.*, **31**, 228–48 (1935); see *Ceram. Abs.*, **14** [11] 281 (1935). H.E.S.

Refractory ladles with a high grog content for steel casting. YA. A. ORLOVSKIĬ. *Ogneupory*, **5** [7] 459–61 (1937).—Weakly-fired refractory ladles and linings were produced for use in the steel industry. The bodies were composed of 56.88 SiO_2, 39.98 Al_2O_3, 1.62 Fe_2O_3, 1.3 CaO, and 0.36% MgO; their refractoriness was about 1739°C. Density varied from 2.1 to 2.23, and resistance to pressure between 346 and 482 kg./sq.cm. The results were highly satisfactory. M.V.C.

Selection of brick for blast furnaces. ALFRED B. SEARLE. *Iron & Steel Ind.*, **11** [1] 7–10; [2] 55–57 (1937).—S. considers in detail the principles of selection for the various zones and discusses the common causes of failure, the avoidable errors, and the modern trends in selection. For the top zone, the best service is given by fireclay brick (the term "aluminous" is undesirable here) sufficiently dense to resist wear and corrosion. Refractoriness may be low (cone 26 to 29). In the second zone, greater refractoriness (cone 30 to 32) is desirable. Fireclay brick with 32 to 38% alumina are amply refractory. Iron oxide should not exceed 2.5%, while 1.5% is better. For the lowest zone, brick must be of low porosity, fine texture, and sufficient refractoriness, with iron oxide not above 2%. For the hearth, bosh, and well, there is still a difference of opinion as to whether fireclay, highly aluminous, or silica brick should be used. The present tendency is to use smaller units of standardized sizes and to require thorough firing. Stipulations of very high refractoriness and high alumina content are now considered less important. Specifications of "maximum refractoriness," "minimum porosity," "greatest strength," and "high insulating power" in the same brick are valueless, as some of these conditions are incompatible. E.H.McC.

Selection of chrome ores for use in steel furnaces. A. E. DODD. *Iron & Steel Ind.*, **10** [11] 497–98 (1937).—Because of the wide variation in ground chrome ore often used for joints in basic open-hearth furnaces, D. offers suggestions regarding the selection. He gives the chemical composition and softening temperatures of various samples. A good chrome ore will not soften below 1800°C. The proportion of silicates present has a profound influence on the properties of the ore, and there seems to be some relation between the silica content and the softening temperature. E.H.McC.

Slag removal from slag pockets of open-hearth furnaces in a single block. M. BEILINOV. *Teoriya & Prakt. Met.*, **9** [3] 21–24 (1937); *Metals & Alloys*, **8** [12] MA744 (1937).—Placing a one-half brick lining (made of silica brick) in a slag pocket and filling the gap between it and the slag pocket walls with sand permitted a comparatively easy removal of slag accumulation in a single block.

Tarasov sandstone as raw material for silica brick. I. S. KAĬNARSKIĬ AND V. A. BRON. *Ogneupory*, **5** [8] 567–76 (1937).—Sandstone from Tarasov contains 99% silica and melts at 1760°. Brick containing 50 to 75% of this sandstone mixed with quartzites are suitable for lining open-hearth furnaces, coke ovens, and electric furnaces. Black silica brick of high grade were manufactured from pure sandstone to which 0.5 to 1.0% "welding slag" was added. M.V.C.

Theory of drying of magnesite products. D. A. KISSIN. *Ogneupory*, **5** [8] 547–51 (1937).—The special way in which magnesite products are dried in comparison with the drying of other ceramic products is dealt with, and the effect of physicochemical factors on drying is discussed. Magnesite should be dried at low temperatures, about 30° to 40°C. M.V.C.

Use of native clays and silicon carbide in the production of zinc muffles. L. WEISSMANN. *Hutnik*, **1936**,

No. 9, pp. 353–55; abstracted in *Referat. Silikatliteratur*, **4** [8] 4336 (1937).—The addition of silicon carbide (25%) to native clay mixes greatly improved the durability of the muffles. M.V.C.

Uses, trends, and developments of refractories in the United States. J. D. SULLIVAN. *Ind. Heating*, **5** [3] 257–64 (1938); see *Ceram. Abs.*, **17** [4] 145 (1938). M.H.

PATENTS

Basic refractory. H. C. LEE (Non-Metallic Minerals, Inc.). Can. 372,664, March 22, 1938 (July 28, 1936). This refractory comprises merwinite, calcium orthosilicate, and periclase. G.M.H.

Brick units for suspended roofs of furnaces. E. H. SANCTON AND D. W. STEWART. Brit. 481,146, March 16, 1938 (Aug. 12, 1936).

Chrome-magnesia refractory. R. P. HEUER (General Refractories Co.). Can. 372,045, Feb. 22, 1938 (Nov. 27, 1936); see *Ceram. Abs.*, **16** [9] 278 (1937). G.M.H.

Firebridges of furnaces burning solid fuel. F. W. ESKE AND E. F. O. ALTENHEIN. Brit. 480,835, March 16, 1938 (April 23, 1937).

Furnace lining. CONRAD HEW-SCHENKER (Meyerhofer & Co.). Can. 371,907, Feb. 15, 1938 (July 28, 1934). A process for the manufacture of a high-temperature corrosive-resistant furnace lining comprises forming the lining with unfired refractory brick which become porous on heating and joining such brick with a refractory mortar. G.M.H.

Furnace wall. J. S. BENNETT (American Engineering Co.). U. S. 2,111,605, March 22, 1938 (Nov. 21, 1935).

Fused refractory. J. D. SULLIVAN (Battelle Memorial Institute). U. S. 2,113,818, April 12, 1938 (Nov. 19, 1934). An article comprises a product produced by melting and fusion of magnesia, silica, and iron oxide, with the magnesia being the chief constituent and being in such proportion with relation to the other oxides that the resulting product will be characterized by iron oxide being in solid solution and with no silicate less basic than the orthosilicate present.

Magnesia refractories. H. H. CHESNY. Brit. 482,340, April 6, 1938 (Sept. 24, 1936).

Means for supporting refractory brick roofs of electric resistance furnaces. AKT.-GES. BROWN, BOVERI & CIE. Ger. 652,267, Oct. 28, 1937; Cl. 24*k*. 5.02; *Chem. Abs.*, **32**, 1591 (1938).

Mullite refractory. G. E. SEIL. Can. 372,721, March 22, 1938 (May 28, 1937). G.M.H.

Production of alumina from clay or other aluminous ore. J. G. STEIN & CO., LTD., AND J. F. HYSLOP. Brit. 480,921, March 16, 1938 (March 17, 1937).

Refractory products. C. ARNOLD (Non-Metallic Minerals, Inc.). Brit. 481,281, March 23, 1938 (July 3, 1936).

Retaining means for furnace wall blocks. E. G. BAILEY AND R. M. HARDGROVE (Babcock & Wilcox Co.). U. S. 2,113,569, April 12, 1938 (Oct. 20, 1927; July 17, 1931).

Walls for furnaces, etc. T. A. R. STAND, U. O. BLOMQUIST, AND H. F. ALBIHN. Brit. 482,143, April 6, 1938 (Oct. 16, 1935).

Terra Cotta

Causes of flaws in flooring tile. L. YA. MISHULOVICH. *Stroitel. Materialy*, **1937**, No. 12, pp. 12–15. P.B. & E.S.

Ceramic floor tile. ONNI DAHL. *Sprechsaal*, **71** [2] 31–33; [3] 41–43 (1938).—D. attempts to classify various types of ceramic floor tile and discusses their manufacture with special regard to the use of native raw materials. M.V.C.

Colored engobes and the present engobing technique. J. JACOBI. *Ziegelwelt*, **67** [16] 165–67; [18] 188–92; [19] 197–99 (1936); abstracted in *Referat. Silikatliteratur*, **4** [3] 3894, 3894A (1937).—J. deals with the manufacture, application, and firing of colored engobes. M.V.C.

PATENTS

Glazing and associated treatment of tile, etc. W. H. SMITH. Brit. 480,878, March 16, 1938 (Oct. 6, 1936).

Method and apparatus for coloring brick, etc. D. WHITEHOUSE AND MARSTON VALLEY BRICK CO., LTD. Brit. 480,922, March 16, 1938 (March 25, 1937).

Method and machine for making clay shingles. DAVIS BROWN. U. S. 2,113,717, April 12, 1938 (May 29, 1935).

Whiteware

Ceramic materials in high-frequency technology. H. HANDREK. *Electrotech. Z.*, **58**, 475–77 (1937).—H. discusses the constitution and characteristics of the following groups of insulation materials: (1) magnesium silicates, (2) rutile bodies, and (3) magnesium titanates. These materials are vitrified and are highly resistant to heat, moisture, alkalis, and acids (with the exception of hydrofluoric acid). Each group has its characteristics and uses. A data table is given. Illustrated. See *Ceram. Abs.*, **16** [1] 25 (1937); **17** [2] 76 (1938). L.E.T.

Ceramic materials in high-tension technology. HORST VON TREUFELS. *Elektrotech. Z.*, **58**, 473–74 (1937).—Ceramic materials, due to their chemical and mechanical properties, are the most suitable construction material for high-tension insulators. Porcelain is the oldest and most used. Latest improvements show a dielectric strength at 50 cycles (Hz) of 34 to 38 kv./mm. (865 to 970 v./mil) on standardized disks 2 to 4 mm. in thickness. Tests on commercial insulators show a dielectric strength of approximately 9 kv./mm. (approximately 230 v./mil) dependent upon the method of manufacture and wall thickness. The dielectric loss depends upon a number of factors. At 50 cycles and at room temperature, the $tg\delta$ for porcelain is 1.7 to 2.5%. The high-compression strength is used for supports for radio towers, etc. The compression strength is from 5000 kg./cm.^{2} to 9000 kg./cm.^{2} (71,000 to 128,000lb./in.^{2}). The latter value is for steatite insulators. The tensile strength of porcelain varies from 450 to 220 kg./

cm.² (6400 to 3130 lb./in.²), and the values are decreased with increase in cross-section. Recent investigations show that fatigue, common in metals, does not occur with ceramic insulators. The difference between dynamic and static strength is only 10%. Steatite bodies show higher mechanical strength but lower resistance to power arcs than porcelain. See *Ceram. Abs.*, **15** [8] 248 (1936). L.E.T.

Ceramic materials in insulation technology. E. Albers-Schönberg. *Elektrotech. Z.*, **58**, 474–75 (1937).—The development of ceramic low-voltage insulators is described. Porcelain and steatite are the principal products. The former consists of a body composed of feldspar-silica glass, undissolved quartz, and a crystalline aluminum silicate. The steatite structure is made up of magnesium-silicate crystals with small quantities of feldspar glass and double silicates of magnesium and aluminum. Low-voltage installation materials are made by the dust-process methods, whereby porcelain is usually pressed with a higher moisture content than steatite. A new group of magnesium-aluminum-silicate bodies has recently been developed (cordierite). A use has been found for high voltage cut-outs (fuse boxes), and their chief characteristics are a very low coefficient of expansion and high resistance to electrical arcs. L.E.T.

Early American porcelain. Wilber Stout. *Bull. Amer. Ceram. Soc.*, **17** [4] 177–78 (1938).

Relationships between grain size of quartz and properties of hard porcelain: I–II. Otto Krause. *Sprechsaal*, **70** [49] 611–12; [50] 623–25; [51] 633–35; [52] 647–48 (1937).—Quartz was introduced into two porcelain mixes in granules of 0 to 15, 15 to 30, 30 to 45, 45 to 60, and 60 to 75μ. K. studied the sintering and working properties and the microstructure of bodies after firing in a porcelain tunnel kiln. The best characteristics were obtained in bodies which contained quartz of a grain size of 15 to 30μ. M.V.C.

PATENTS

Compositions for making spark plugs. Robert Bosch A.-G. Ger. 652,354, Oct. 29, 1937; Cl. 80*b*. 8.18; *Chem. Abs.*, **32**, 1889 (1938).—Powdered corundum is heated to about 1500° with a subordinate proportion of a natural or synthetic zeolite in which the alkali oxide has been replaced, wholly or in part, by an alkaline earth oxide, and, if desired, all or part of the SiO_2 has been replaced by TiO_2. An example is given.

Spark plug. C. G. Cramer. Can. 372,090, Feb. 22, 1938 (March 18, 1937). George McKinley (B. G. Corp.) Can. 372,150, March 1, 1938 (Aug. 4, 1937). E. V. Taylor. Can. 371,981, Feb. 15, 1938 (Sept. 24, 1935). W. J. Vincent. Can. 372,880, March 29, 1938 (March 3, 1937). G.M.H.

Spark-plug insulators. General Motors Corp. Fr. 815,921, July 26, 1937; *Chem. Abs.*, **32**, 1889 (1938).—These are made from recrystallized Al_2O_3 and an aluminate of Ba, Sr, Ca, Zn, or Cd.

Treatment of clay. Karl Schulz. Ger. 652,074, Oct. 25, 1937; Cl. 80*b*. 12.01; *Chem. Abs.*, **32**, 1889 (1938).—Clay for making pottery, etc., is de-aired and improved by steaming it in an open container, which is then sealed until the clay has cooled.

Equipment and Apparatus

Advances in applied photography. W. Clark. *Trans. Amer. Inst. Chem. Engrs.*, **32**, 111–24 (1936).—Recent developments in photography are reviewed. Sensitizing for the infra-red has been advanced by the discovery of a group of dyes known as the tricarbocyanines. Photographs free from reflections and glare are possible by means of polarized light. By means of Grenz ray radiography, it is possible to study the structure of textile materials. High-speed cameras, weighing only 15 lb. and capable of taking from 8 to 5000 pictures per second, are now available. Color photography has been greatly enhanced by the use of the additive and subtractive Kodachrome processes. H.E.S.

Automatic temperature regulation for gas-heated laboratory drying chambers. Erich Boye. *Chem.-Ztg.*, **61**, 953 (1937); *Chem. Abs.*, **32**, 1517 (1938).—An easily constructed apparatus, depending on a Hg valve actuated by pressure of air in a bulb in the drier and accurate to ± 1°, is described in detail. Illustrated.

Auxiliaries—steam or electric drive? T. Baumeister. *Combustion*, **8** [9] 25–30 (1937).—The present extensive use of high-pressure topping installations has revived consideration of the steam-turbine drive for certain auxiliaries requiring large amounts of power. B. analyzes the relative advantages of steam and electric drive for this purpose and presents several cyclic diagrams to illustrate the points raised. H.E.S.

Density and associated quantities and their application to ceramics. Henry Cassan. *Chaleur & Ind.*, No. 214, pp. 216–23 (1938).—Methods of density determination by Le Chatelier's densimeter, the pycnometer, weight and measure, and the hydrostatic balance are described in detail with a consideration of the errors and applications of each. Formulas for the calculation of absorption, open-pore volume, closed-pore volume, bulk density, etc., are developed. Nomographs make it possible to read these quantities directly from the experimental data. V.D.F.

Drier articles. Anon. *Ind. Bull. of A. D. Little, Inc.*, No. 112 (1936).—A process of air drying of industrial products has been developed in which no heat need be supplied within the drier, no fresh air is used, and no wet air is thrown away. Moist air leaving the drier is passed in contact with a strong hot solution of lithium chloride which absorbs the water vapor and heats the air. The dried hot air is then returned to the drier, and no heat need be supplied to the drier or preheater, except to make up for conduction and leakage through the drier walls. Heat must be applied to evaporate the water from the lithium chloride solution. A steam saving of 70% is claimed for this process over typical steam-heated air driers. H.E.S.

Drying methods. V. N. Zimin. *Ogneupory*, **5** [6] 384–95 (1937).—Experiments made to accelerate and improve the drying of glasspots are described. Two methods, "thermal diffusion" and "electric diffusion," were de-

veloped. The former method is based on heating of the outside surfaces of the refractory pot, while in the latter, both the inside and outside walls of the pot are heated by means of electrodes. The latter method was found to be more satisfactory. M.V.C.

Effect of temperature and humidity on rate of drying of clay shapes. H. H. MACEY. *Brit. Clayworker*, **46** [548] 306–13 (1937).—The drying of a clay body may be divided into two stages: a constant-rate period and a falling-rate period. During the constant-rate period, the rate of drying per unit surface area is independent of the size of the clay block. During this period and under conditions where the clay receives all of its heat from the air passing over it, the clay assumes the wet-bulb temperature, and the rate of drying obeys the same law as that of a free water surface. Furthermore, under these conditions the rate of drying varies directly with the depression of the wet-bulb thermometer, the velocity of the drying air being constant. In the latter part of the falling-rate period, increase of temperature results in an increased drying rate independent of the humidity. See "Principles—," *Ceram. Abs.*, **13** [8] 224 (1934); "Time—," *ibid.*, **16** [7] 214 (1937); "Experimental—," *ibid.*, **17** [3] 110 (1938). R.A.H.

Electric temperature measurements. JENIS MENDE. *Pofüzetec Temezettudimanyi Köglēnyhöz*, **69**, 76–83 (1937); abstracted in *Chem. Zentr.*, **1938, i**, 2219.—M. describes various types of thermoelectric, resistance, and radiation pyrometers. M.V.C.

Electron furnace. ANON. *Electronics*, **10** [3] 17 (1938).—Ralph R. Hultgen has developed a new form of electronic furnace capable of obtaining a temperature of 4500°F without contaminating the metal charge enclosed in it. The mechanical energy of electronic bombardment, similar to that which heats the plates of transmitting tubes, heats the crucible containing the charge. H.T.

Experimental study of the molecular theory of lubrication. O. WITTROCK. *Oel & Kohle*, **13**, 979–81 (1937); *Brit. Chem. Abs.-B*, **56**, 1299 (1937).—Tests show that the surfaces of bearings are, in practice, so uneven with regard to molecular dimensions that conditions of full-fluid as opposed to those of semifluid or boundary lubrication apply. This is held to explain the lack of consistency in the classification of oils by testing machines of different designs.

Grindability and grinding characteristics of ores. FRED C. BOND AND WALTER L. MAXSON. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 888, 22 pp.; *Mining Tech.*, No. 2 (1938).—Several hundred grindability tests are described in which a certain size feed was run through a small laboratory ball mill and screened. These show the rate of production of a finer size per revolution. They are mostly on metallic ores, but there are a few on quartz, nepheline syenite, abrasive, etc. To improve surface calculations from screen analysis, the sample is washed on a 200-mesh sieve until the fines are all through and then dried and screened; the individual screens are calibrated. Tables and graphs are given to aid calculations of surface area. The amount of work necessary to produce a unit area of new surface is measured on a pendulum impact machine that shears a metal pin, crushes the ore, and uses its remaining energy in swinging up through a measured arc on the other side. This device avoids the absorption of energy in the supports when the material is crushed by a directly falling weight. Portland cement clinker gave values 9.6% less than those of the Portland Cement Assn., who used a direct impact test. One revolution of a mill produces the same amount of new surface when grinding to different sizes and with different circulating loads. A discussion and summary are included. W.D.F.

Heater closures. G. A. FRICKE. *Combustion*, **8** [9] 31–33 (1937).—F. discusses progressive developments in the design of heater heads to keep pace with the trend toward higher steam pressures and the employment of larger units. Bolts and gasketed joints have been replaced, in the case of high pressures, by designs that transmit the hydraulic load on the cover directly to the barrel of the head by shear. H.E.S.

Heat-resisting alloy castings. H. DIXON. *Ind. Heating*, **5** [3] 224–28 (1938).—Four groups are distinguished: chrome irons, chrome nickels, low-nickel chromes, and high-nickel chromes. They contain in general 0.40 to 0.70% C (except the chrome nickels which contain below 0.3% to give strength at high temperatures but with reduced ductility); 15 to 35% Cr, supplying oxidation resistance; 0 to 80% Ni, to give an austenitic microstructure and higher load-carrying capacity at elevated temperatures than in ferritic structures; up to 1.5% Si as deoxidizing agent; up to 3% Mo as a grain refiner; and a small amount of V, Co, Ti, and W for grain refinement, deoxidation, and strength. Tables give physical properties and classification of such alloys by manufacturers and trade names together with fields of application. M.H.

Higher magnetic permeabilities. R. M. BOZARTH. *Bell Lab. Record*, **16** [7] 229–31 (1938).—The discovery, over twenty years ago, that certain alloys of iron and nickel have remarkable magnetic properties, has resulted in extensive investigation of the factors controlling the unusual behavior of these alloys. Recently, by combining in a single alloy several of the factors on which high magnetic permeability depends, a substance has been developed having ten times the permeability of the best commercial permalloy. The material and its processing are described. Factors favoring ease of magnetization are discussed. The chief value of the present experiments is that they confirm the principles arrived at by other studies and show that the separate factors determining the remarkable magnetic characteristics of permalloys are additive in their actions. Illustrated. P.S.D.

High-temperature properties for some alloys of particular interest to the Navy. WILLIAM C. STEWART. *Jour. Amer. Soc. Naval Engrs.*, **50** [1] 107–32 (1938).—Creep-test data for C-Mo, Cu-Mo, and Cr-Mo cast steels and for composition "G" and "M" cast bronzes are presented in numerous curves and tables. W.H.B.

Krupp hard metal, Widia. K. NISCHK. *Oberflächentech.*, **15** [6] 55–56 (1938).—The material is a sintered W carbide powder, with additions of Co or Ni up to 20%, of a natural hardness which remains practically the same up to 900°C. N. describes manufacturing methods, types, and fields of application. M.H.

Materials for high pressure-high temperature steam service. GUY CHADWICK. *Jour. Amer. Soc. Naval Engrs.*, **50** [1] 52–84 (1938).—C. gives a comprehensive review of the entire field of application of materials for

Naval piping, flange bolts, valves, superheaters, turbine assemblies, etc. A bibliography is appended. W.H.B.

Metal spraying: fundamentals and applications. R. L. DENNISON. *Jour. Amer. Soc. Naval Engrs.*, **50** [1] 85–106 (1938).—D. reviews the various methods, applications, and history of metal spraying. The type of deposit obtained with wires of ferrous and nonferrous metals is discussed and shown in micrographs. The physical properties of the spray castings, porosity, adhesion to base, etc., are discussed from data in the literature. Navy tests made on adherence of sprayed (*a*) German silver, (*b*) Al, (*c*) council bronze, (*d*) Cd, (*e*) Cu, and (*f*) Zn on steel torsion specimens showed that *a* and *b* flaked off below the yield point of steel, *c* and *d* flaked at the yield point, and *e* and *f* came off at an angle of twist of 150° or 75° above the angle of twist at the yield point. Protection against corrosion by sprayed anodic metals and against oxidation by sprayed Al is discussed as the most successful applications. The corrosion protection, however, is not always entirely predictable. Its use in building up worn shafts, journals, pump plungers, etc., is considered successful when the principal stress to which it is subjected is compression, since the tensile strength is quite low. A bibliography is appended. W.H.B.

Micrometer for enamel slips and glazes. J. E. ROSENBERG. *Ceram. Forum*, **3** [2] 1 (1936).—Control of application of enamel slips and glazes is greatly aided in the enamel and pottery industries by a determination of the specific gravity and viscosity of the applied material. A metal viscometer, devised by the O. Hommel Co., determines within a few minutes both the specific gravity and viscosity of the desired liquid. The instrument, which consists of a metal tube with a cap at one end and an accurately machined hole at the other, may be filled with a known volume of slip; it is easily weighed and then inverted, and the time for the known volume of slip to run out serves as a measure of its viscosity. The parts are all replaceable, and the instrument serves as an excellent micrometer for the glaze or enamel operator. H.E.S.

New tables of the psychrometric properties of air-vapor mixtures. WILLIAM GOODMAN. *Heating, Piping, & Air Conditioning*, **10** [1] 1–7 (1938).—The psychrometric data presented are based on the new Keenan-Keyes steam tables. G. describes the way in which the data were computed, their use in solving air-conditioning problems, and the method of computing the heat to be removed when cooling and dehumidifying air. Sample calculations and an explanatory diagram and table are included. J.L.G.

Reference tables for iron-constantan and copper-constantan thermocouples. W. F. ROESER AND ANDREW I. DAHL. *Jour. Research Nat. Bur. Standards*, **20** [3] 337–55 (1938); R.P. 1080. Price 5¢.—Tables have been prepared giving corresponding values of temperature and thermal electromotive force at various temperatures from −200° to 1000°C for iron-constantan thermocouples. Similar tables from −200° to 400°C for copper-constantan thermocouples, although not new, have been included for completeness. The temperature-e.m.f. relations embodied in these tables are such that (1) each can be reproduced with materials generally and readily available; (2) each is the same (within ± ¾%) as the temperature-e.m.f. relation of a large percentage of such thermocouples of that type now in use; (3) each is near the mean of the extreme limits of the temperature-e.m.f. relations for thermocouples of that type; (4) the table for iron constantan is near the existing table most widely used, while the one for copper constantan is the one most widely used; and (5) the constantan used with one element to reproduce one table can be used with the other element to reproduce the other table. The authors also give (*a*) average values of the thermal e.m.f. of copper, iron which is generally available, and constantan against platinum, as a guide in selecting materials to yield any specified relation between thermal e.m.f. and temperature for thermocouples of these types, and (*b*) the variation in thermal e.m.f. that might be expected between samples of these materials from the same and from different lots. R.A.H.

Selection of driers. F. A. M. WÜLFINGHOFF. *Brennstoff- & Wärmewirt.*, **19**, 155–63 (1937); *Chem. Abs.*, **32**, 1517 (1938).—W. discusses driers using artificial heat. General considerations are stated, driers are classified, and conditions are given for drying various materials. Several types of driers are illustrated. Suggestions are made as to the type of drier for various types of material. Mathematical equations are given to assist in drier calculations.

Simple spring torsion balance. A. C. FABERGE. *Jour. Sci. Instruments*, **15** [1] 17–21 (1938).—This inexpensive torsion balance uses a helical spring of phosphor-bronze wire as the elastic element. This is arranged as the only support of the torsion arm. Relative sensitivity is about 0.002 of the maximum load. Absolute sensitivity is at least 0.001 mg. by direct reading. 3 figures. J.L.G.

Vacuum deaërator. ANON. *Chem. Industries*, **38** [3] 278 (1936).—A vacuum deaërator has a series of convex and concave baffles arranged alternately so that the liquid will flow in thin films in such a way as to provide the maximum amount of exposed surface. The baffles are separated by spacer rings and can be removed very quickly for cleaning. Considerable space is provided in the upper part of the deaërating vessel to permit the settling of the foam which is frequently produced when liquids are first exposed to high vacuum. Vacuum is maintained by a steam jet evacuator. A single-stage evacuator produces a vacuum between 27.5 and 28.0 in. When required, a two-stage evacuator is furnished to produce a vacuum up to 29.7 in., except as limited by the vapor pressure of the liquid. A mechanical pump can be used in plants where live steam is not available for the evacuator. P.G.H.

Vacuum drying oven. A. GALLENKAMP AND CO., LTD. *Jour. Sci. Instruments*, **15** [1] 32 (1938).—The oven is fitted with automatic temperature control which will hold the oven within ±1°C at any temperature between 60° and 135°C. A vacuum of 26 in. can be obtained without rubber grease on the precision ground door and oven surfaces. With high-temperature grease, 30 in. can be attained. A three-way stopcock allows the entrance of dried air after evacuation. The working space in the oven is 3 in. high x 7½ in. wide x 15 in. long. The weight of the oven is 93 lb. The price is £37 10s. Illustrated. J.L.G.

BOOKS AND BULLETINS

Applied Fluid Mechanics. MORROUGH P. O'BRIEN AND GEORGE H. HICKOX. McGraw-Hill Book Co., New York. 360 pp. Price $3.50. Reviewed in *Science News Letter*, **32** [866] 320 (1937).—The behavior of fluids in theory and practice, with emphasis on the latter, is discussed. The scope of the book is wide; it covers the mechanics of gases and liquids as well as internal fluid mechanics. P.G.H.

List of respiratory protective devices approved by the U. S. Bureau of Mines. H. H. SCHRENK. *U. S. Bur. Mines Information Circ.*, No. 6952, 6 pp. Free.—S. lists all respiratory protective devices approved by the U. S. Bureau of Mines as of April 10, 1937. See *Ceram. Abs.*, **16** [2] 77 (1937). R.A.H.

Ore dressing studies: (A) Use of wetting agents in flotation. R. S. DEAN, J. BRUCE CLEMMER, AND S. R. B. COOKE. **(B) Flotation of complex molybdenum-vanadium ores from Arizona.** J. BRUCE CLEMMER AND S. R. B. COOKE. **(C) Short-column hydraulic elutriator for subsieve sizes.** S. R. B. COOKE. *U. S. Bur. Mines Repts. Investigations*, No. 3333, 50 pp. Free.—These papers comprise a progress report of the Metallurgical Division on studies of ore dressing that have been under way in the Division during the past year. R.A.H.

PATENTS

Apparatus for manufacturing pottery ware. W. J. MILLER AND ASHLEY REEK. U. S. 2,114,254, April 12, 1938 (Oct. 17, 1935).

Apparatus for producing slip-cast ceramic bodies. J. G. STEIN & CO., LTD., AND H. C. BIGGS. Brit. 481,217, March 23, 1938 (Nov. 30, 1936).

Baffle apparatus for separating dust from air. JAKOB HANDTE. Fr. 817,032, Aug. 24, 1937; *Chem. Abs.*, **32**, 1524 (1938).

Baffle apparatus for separating dust from gases. FRITZ PROBOL. Ger. 652,310, Oct. 30, 1937; Cl. 12*e*. 2.01; *Chem. Abs.*, **32**, 1524 (1938).

Centrifugal apparatus for separating dust from gases. WESTFALIA - DINNENDAHL - GRÖPPEL A.-G. (Alfred Roemelt, inventor). Ger. 653,007, Nov. 15, 1937; Cl. 12*e*. 2.01; *Chem. Abs.*, **32**, 1524 (1938).

Classifier for dry impalpable fines. PAUL GERHARDT (William G. Broadfoot). U. S. 2,113,885, April 12, 1938 (Dec. 24, 1936).

Defoaming method and means. H. H. YOUNG, JR. (Industrial Patents Corp.). U. S. 2,108,912, Feb. 22, 1938 (July 9, 1935). A defoamer comprises wax, aluminum stearate, and stearic acid.

Drying apparatus. HERMANN POSSEKEL. Can. 371,900, Feb. 15, 1938 (April 29, 1935). G.M.H.

Earth working tool. N. E. JERSEY (W. A. Riddell Corp.). U. S. 2,113,917, April 12, 1938 (Jan. 27, 1937).

Electric furnaces. NORTON GRINDING WHEEL CO., LTD. Brit. 481,229, March 23, 1938 (June 6, 1935).

Means for degasifying clay in extrusion presses. SCHMIDT & CO. Ger. 652,116, Oct. 25, 1937; Cl. 80*a*. 26; *Chem. Abs.*, **32**, 1889 (1938).

Methods of heating rapidly revolving tube furnaces for melting glass, silicates, and other refractory material. G. ZOTOS. Brit. 482,163, April 6, 1938 (Feb. 14, 1936).

Spray gun. A. F. JENKINS. Can. 372,851, March 29, 1938 (March 13, 1937). G.M.H.

Viscosimeter. R. D. DELAMERE AND W. M. HUTCHEON (A. R. Clarke & Co., Ltd.). Can. 372,772, March 29, 1938 (June 18, 1937). G.M.H.

Kilns, Furnaces, Fuels, and Combustion

Alabama coals—their classification and analyses. P. B. PLACE. *Combustion*, **8** [7] 40–43 (1937).—The individual coal seams are traced through the various counties, the coals are identified by the county and trade names, and their characteristics and analyses are given. Knowing the source and moisture and ash content of an Alabama coal, a complete analysis may be set up from the values given in the tables which will be sufficiently accurate for most power plant purposes. H.E.S.

Choice of a gas burner system. RAYMOND F. MANN. *Amer. Gas Jour.*, **148**, 14 (Feb., 1938).—Gas burners are classified as those using (1) low pressure air, (2) high pressure air, and (3) high pressure gas. The advantages and disadvantages of each type are listed. Type 2 burners have the greatest number of operating disadvantages and are most expensive both as to installation and operating costs. Type 3 is considered the least expensive to install and operate if piping costs are included and is recommended for use in plants having a large number of furnaces. The initial investment in burner equipment and compressor is slightly lower for type 1 as compared to 3 and is recommended for use in small plants having only one or two furnaces. B.C.R.

Combustion temperature of solid and gaseous fuels. KOVACHE. *Arts & Métiers*, **91** [206] 240–46 (1937).—Theoretical considerations and computations are presented. R.W.D.

Experimental determination of flame temperature; methods and results. YVON LAURE AND HUBERT GAUDRY. *Chaleur & Ind.*, No. 213, pp. 44–54 (1938).—Errors in the thermoelectric method for the accurate measurement of flame temperature may be minimized by diminishing the radiation loss from the thermocouple wire and by increasing the convection factor from the flame to the wire. The latter may be used to extrapolate to the true flame temperature by measuring with a number of thermocouples having wires of successively smaller diameters. A second method of flame temperature measurement is the plotting of the temperature of an electrically heated resistance wire against the current flow, first *in vacuo* and then in the flame. The intersection of these two curves represents the true flame temperature because the heat input in the wire exactly furnishes the heat lost by radiation as it did during its standardization, the wire being unaffected by convection from the flame since it is at the same temperature. The temperature of the wire is measured by an optical pyrometer. An optical method is that of observing a controlled heating element with an optical pyrometer. When the flame is interposed in the line of vision, the reading of the pyrometer will not

change if the flame is at the same temperature as the standard source. In coloring nonluminous flames by metallic salts for temperature measurements, care must be taken lest the salt dissociate only in a localized part of the flame and give a reading lower than the maximum. Another pyrometric method is to pipe off a sample of the gases immediately after combustion. The temperature can be computed from the heat of reaction, gas composition, specific heats, and constants of dissociation. Another method is the measuring of the electrical conductivity across the flame when treated with the salt of an alkali. Sahi's equation gives the temperature. Flame temperatures, both measured and calculated, are given for a number of gases. V.D.F.

Flue-gas separators. K. HEINRICH. *Combustion*, **8** [8] 36–38 (1937).—H. reviews European practice in the use of electrostatic precipitators and the mechanical separation of the wet and dry type. Some representative types are discussed, and their characteristics and performances are compared. H.E.S.

Heat-transmission value and heat capacity. B. KOCH. *Mitt. Forsch.-Anstalt. Gutehoffnungshütte Oberhausen A.-G.*, **6** [2] 52–57 (1938).—K. explains a new simple method by which the maximum temperature of a space, *e.g.*, the heating chamber of a furnace, can be determined, for constant surrounding conditions and constant heat supply, by the temperature increase-temperature diagram. The desired temperature is found as the intersection on the abscissa axis, $dt/dz = 0$; the heat transmission value as the quotient of the supplied heat over the maximum temperature, $K = Q/t$; and the heat capacity (heat content) as the quotient of the supplied heat over the inclination of the temperature curve, dt/dz, $C = Q/(dt/dz)$. A numerical example shows the practical application. M.H.

Hydraulic theory of furnaces. V. KUROEDOV. *Teoriya & Prakt. Met.*, **9** [4] 20–40 (1937); *Metals & Alloys*, **8** [12] MA744 (1937).—The hydraulic theory of furnaces is compared in detail with the energetic theory. The latter is more reasonable.

Identification of chemical reactions proceeding in the midst of flames. M. PRETTRE. *Chaleur & Ind.*, No. 213, pp. 38–44 (1938).—The work of a large number of investigators is cited to show that combustion in oxygen-hydrogen and in carbon monoxide-oxygen mixtures occurs as chain reactions, of either the straight or branched type. Study of these reactions by the method of sampling with a cold tube is unsatisfactory because the gas reactions do not cease but alter in cooling. Spectrographic analysis of the flame has been of great value, particularly when applied to a diluted flame, although there is great difficulty in interpreting the results. Paneth's method of metallic mirrors identifies individuals in the flame by noting the compounds formed on mirrors of Hg, Pb, Sb, Te, As, Bi, etc. The use of inhibitors has identified certain of the intermediate members of the chain reactions such as H, OH, etc. V.D.F.

Kansas and Missouri coals—their classification and analyses. P. B. PLACE. *Combustion*, **8** [10] 37–40 (1937).—The individual seams are traced through various counties, the coals are identified by county and trade names, and their characteristics and analyses are given. Knowing the source and moisture and ash content of a Kansas and Missouri coal, a complete analysis may be set up from the values given in the tables which will be sufficiently accurate for most power plant purposes. H.E.S.

Possible modes of occurrence of gas in coal. P. RODHAIN. *Ann. Mines*, **10** [13] 101–17, 131–48 (1937); *Brit. Chem. Abs.–B*, **56**, 1291 (1937).—The occlusion of gas in the coal pores, with or without adsorption, and the formation of solid solutions are discussed mathematically.

Preventing spontaneous heating of large coal piles. M. K. DREWRY. *Combustion*, **8** [8] 28–32 (1937).—Packing, asphalting, and covering with a 1-ft. layer of fine air-tight coal are individually involved in several experiences with 50-ft. piles of 40,000 to 120,000 tons which P. discusses. Fine-coal covering of piles has proved effective and practical and has been adopted by the Milwaukee Electric Railway and Light Co. for storage of coal. H.E.S.

Sources of error in determining the calorific value of fuels. H. H. MÜLLER-NEUGLÜCK. *Glückauf*, **73**, 345–55 (April 17, 1937); abstracted in *Fuel*, **17** [1] 30 (1938).—The experimental arrangements and the calculations for the determination of the calorific values of fuel are laid down in DIN, DUM 3716; nevertheless, considerable variations have been found in the investigations of the same coal in different laboratories. With the object of revision of the above standards, a large number of comparative investigations has been made in the determination of calorific values, methods of calculation, and experimental conditions. For scientific calculations the formulas of Roth, Schuttes, and Nübel are recommended, and examples of these are given. Various experiments are described in detail together with the steps to be taken to insure the accuracy of the determinations and temperature measurements. Comparative tables of results are given for oil, coal, brown coal, and coke. M.H.

Speed of propagation of flame in a homogeneous combustible mixture under constant pressure and theory of the blue flame. G. RIBAUD. *Chaleur & Ind.*, No. 213, pp. 23–28 (1938).—By a mathematical consideration of the theory of the blue cone in combustion at an orifice, R. established the fact that the relation between the surface area of the blue cone and the size of the orifice is proportional to the relation between the flow rate of the combustible mixture and the speed of flame propagation in such a mixture. This limits the flame in the maximum that may be maintained without breaking the blue flame and causing incomplete combustion and the minimum that may be maintained without extinction. The speed of flame propagation increases with rise in temperature. V.D.F.

Storage of coal supplies. F. J. MATHEWS. *Eng. & Boiler House Rev.*, **49**, 793 (1936).—During storage, coal absorbs oxygen slowly due to oxidation, resulting in a loss of calorific value. Coal reaching a temperature of 150° to 160°F should either be used or cooled; at 180° to 200°F ignition may occur, depending upon the amount of easily oxidizable organic matter present. Segregation of fines and lumps should be avoided. Most methods of piling coal depend on the following principles: (1) the exclusion of all air, and (2) provision for uniform ventilation throughout the coal pile. B.C.R.

BULLETINS

Annual report of research and technologic work on coal for the fiscal year 1937. ARNO C. FIELDNER. *U. S. Bur. Mines Information Circ.*, No. 6992, 44 pp. Free. R.A.H.

Performance of a Baum-type coal-washing jig. H. F. YANCEY AND M. R. GEER. *U. S. Bur. Mines Repts. Investigations*, No. 3371, 18 pp. Free. The results of a study, the purpose of which was to evaluate the principal factors, size and specific gravity, upon which the separation of coal and impurity depend, are presented. R.A.H.

Performance of a pulsator-type coal-washing jig. H. F. YANCEY, M. R. GEER, AND R. E. SHINKOSKEY. *U. S. Bur. Mines Repts. Investigations*, No. 3372, 19 pp. Free. A study of the efficiency and mechanism of separating coal and impurities with this type of machine is presented. R.A.H.

PATENTS

Gas purification. F. G. COTTRELL (Research Corp.). Can. 372,342, March 8, 1938 (July 22, 1936; in U. S., Aug. 14, 1935). G.M.H.

Tunnel kiln for ceramic products. GENERAL MOTORS CORP. Fr. 815,986, July 27, 1937; *Chem. Abs.*, **32**, 1889 (1938).

Geology

Acid and base binding capacities and viscosity relations in certain whiteware clays. EDWARD C. HENRY AND NELSON W. TAYLOR. *Jour. Amer. Ceram. Soc.*, **21** [5] 165–75 (1938).

Apatite, nepheline, and rare-earth mining in the Kola Peninsula. G. W. TYRRELL. *Nature*, **141** [3565] 354–55 (1938).—The geology, minerals, and mines of the Kola Peninsula in Russia are briefly considered. 1 geological map. J.L.G.

Bauxite as an absorbent for percolation filtration. R. H. HUBBELL, JR., AND R. P. FERGUSON. *Refiner & Natural Gasoline Mfr.*, **17** [3] 104–108 (1938).—The absorbent or decolorizing power of a large number of bauxite samples from various deposits are compared. Bauxite is compared with ordinary fuller's earth. Laboratory data indicated little or no relation between the chemical composition and the decolorizing efficiency of bauxite. The physical characteristics of bauxite which bear upon its usefulness as a decolorizing agent are bulk density and susceptibility to disintegration in steaming. The bulk density is a measure of the available decolorizing surface in the material. The absorptive characteristics of bauxite are profoundly influenced by the temperature at which the material is calcined before using. Numerous tables of physical and chemical data are given. J.J.H.

Bentonite in Italy. V. C. *Ind. Chim.*, **25** [288] 16 (1938).—A deposit of bentonite was recently discovered in Italy, on the island of Ponza near Naples. Italian bentonite closely resembles that of Wyoming; as it contains little iron oxide, it is whiter than the latter. See *Ceram. Abs.*, **16** [7] 217 (1937). R.W.D.

Beryllium in bauxites. TIBOR SZELÉNYI. *Math. naturw. Anz. ungar. Akad. Wiss.*, **56**, 231–46 (1937); *Chem. Abs.*, **32**, 1616 (1938).—A Zeiss quartz spectrograph "Q 24" and the method of Goldschmidt-Mannkopff were used. Rock in amount of 0.003 g. was analyzed in pure C electrodes containing only about 0.0005% BeO. Current intensity was 4 to 5 amperes at the ignition, increasing after 30 sec. to 12 to 14 amperes. Hungarian bauxites from Gánt contained 0.005 to 0.01% BeO which agrees with the data obtained by Goldschmidt and Peters. No connection of Be content with the chemical composition of bauxite could be found. The obtained BeO content seemed to be too low to make its industrial working up rational. Some kaolins and clays were examined for BeO content. They mostly showed values equal to those of bauxites. Some kaolins, however, were very low in BeO, which probably can be explained by some genetic feature of their formation.

Brick of slate debris accumulated over 400 years. ANON. *Stone*, **59** [1] 32 (1938).—Experiments are reported at Glasgow, through the mineral trade notes publication of the Department of the Interior, for the purpose of utilizing the waste from the famed Ballachulish slate quarries. This debris has been accumulating at the three quarries for more than 400 years and among other utilizations being considered is that of making this waste into brick. P.G.H.

Clay minerals in Illinois limestones and dolomites. R. E. GRIM, J. E. LAMAR, AND W. F. BRADLEY. *Jour. Geol.*, **45** [8] 829–43 (1937).—Modern descriptions of argillaceous sedimentary rocks and of clay grades in insoluble residues should state the kinds and amounts of clay minerals present. The clay-mineral content of limestones and dolomites has had little or no previous study. The major clay minerals are summarized. All clay fractions in the insoluble residues from 35 samples of Illinois limestones and dolomites (Ordovician to Pennsylvanian) contained illite, 20 contained kaolinite, and 3 contained beidellite (?). Ordovician samples contained illite only. Kaolinite is dominant in the Pennsylvanian samples. A clay-mineral analysis of the 35 samples studied is given. Much of the illite was probably derived from beidellite and the kaolinite is probably detrital. Such clay-mineral data are economically important in calculating free silica from a chemical analysis. Tables are included. A.C.B.

Colloidal properties of clay suspensions and gels. CHARLES E. REED. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 871, 23 pp.; *Petroleum Tech.*, **1**, No. 1 (1938).—R. gives a review of recognized clay properties. Montmorillonite is formed from two layers of silicon atoms bound to one plane of aluminum atoms between them through layers of oxygen atoms. A crystallite is one layer thick and can extend in its own plane indefinitely. One or more crystallites stacked in a pile give a clay particle. In montmorillonite this swells when water is added, as the water goes between the crystallites and forces them apart. In kaolin 90% of the particles have dimensions greater than 500 mμ and can be resolved by a microscope, but bentonite is much finer; 75% of one sample was below 50 mμ and was rather uniform in size, with a maximum near 25 mμ. The smallest particles are primarily responsible for the gelation. A 0.1% bentonite suspension

of 14 mμ average size will set or gel. A pure hydrogen bentonite will not set under some conditions, but the addition of an electrolyte will cause it to set in a short time; this time of set keeps on decreasing for about 28 days. Heating will cause more rapid gelation and is largely irreversible. The purely mechanical theory of gelation needs clay particles with a length to thickness ratio of 1000:1. This has not been disproved, but another theory is offered, in which the attractive force between the particles is balanced at a certain distance by the repulsive force of the ions surrounding the particle. Thus there is no tendency to move, and a gel is formed by locking the particles. Some important unsolved problems are the measuring of the mechanical properties, the electrochemical behavior, and the effects of addition agents.
W.D.F.

Concentration tests on Tennessee Valley barite. H. S. RANKIN, ROBERT A. LAURENCE, F. A. W. DAVIS, EDWARD C. HOUSTON, AND LYNN L. MCMURRAY. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 880, 13 pp.; *Mining Tech.*, **2**, No. 2 (1938).—Barite occurs in two important deposits in the residual clay of the upper Knox dolomite. The impurities are iron and silica. Some samples can be concentrated with decrepitation with heat and screening, most samples can be concentrated by flotation, and the barite can be bleached by calcining and by acid treatment.
W.D.F.

Concentration of titanium dioxide in clays. ATTI SALMINEN. *Suomen Kemistilehti*, **9A**, 1–4 (1936); abstracted in *Referat. Silikatliteratur*, **4** [3] 3865 (1937).—The origin of titanium dioxide in clays, sands, and loams is discussed in detail. Mica is the carrier of TiO_2 in clays.
M.V.C.

Critical study of methods of determining exchangeable bases in clays. ROBERT P. GRAHAM AND JOHN D. SULLIVAN. *Jour. Amer. Ceram. Soc.*, **21** [5] 176–83 (1938).

Deposits of usable minerals, rocks, and earths in Austria. W. PETRASCHECK. *Z. Berg.- Hütten.- Salinenwes. deutsch. Reich*, **85**, 266–73 (1937); abstracted in *Chem. Zentr.*, **1937, ii**, 3932.—P. describes deposits of graphite, magnesite, talc, asbestos, baryta, feldspar, gypsum, phosphate, kaolin, diatomite, refractory clays, quartzite, and quartz sand.
M.V.C.

Elements of flotation practice. E. J. PRYOR. *Mining Mag.*, **57**, 137–48 (1937).—The froth is controllable for (1) elasticity, (2) durability, (3) texture, (4) height, (5) persistence, (6) length of contact with mineral, and (7) selectivity. It can not be collected without 1 and 2; 3, 4, and 5 are important in letting entrapped pieces of gangue sink; and 6 should be as long as possible. Wetability or floatability is the degree of readiness with which the air film on the surface is displaced by water. It depends on surface conditions only; the harder the material is to wet, the easier it is to float. Freshly ground material is more easily wetted. The chemical and physical conditions on the particle's surface and hence the floatability may be controlled by various treatments, including p_H control. The reagents used in flotation include (1) frothers, (2) promoters, (3) depressants, (4) activators, (5) sulfidizers, (6) p_H regulators, and sometimes (7) flocculators or dispersers. One reagent may combine several of these properties. The froth would not be formed in a pure liquid, hence the addition of very small quantities of 1; 2 are adsorbed, sometimes selectively, on the mineral to help it float; 3 prevent the flotation of certain minerals; 4 refloat minerals once depressed; 5 react with an oxide to form a sulfide and so aid flotation; and 6 are used, as certain minerals float best at certain values. Crushing should be fine enough to liberate the ore, which may be quite fine, although the gangue should be kept coarse. The flow sheet should be worked out by trial on small batches and then in a pilot plant.
W.D.F.

Feldspar from pegmatites from North Kareliya. L. L. SOLODOVNIKOVA. *Trav. inst. Lomonossoff géochim., crist. minéral.*, **1935**, No. 5, pp. 3–85 (in German 85–86); *Chem. Abs.*, **32**, 1617 (1938).—Microscopic and chemical analyses and density determinations are tabulated, and varieties of the feldspar are described. Twenty-four references.

Fire clays in Scotland. C. F. DAVIDSON. *Times Trade & Eng.*, **42** [889] xli (1938).—Fire clays in the Midland Valley of Scotland are confined mainly to the Millstone Grit Formation; those of Glenboig, Castlecary, and Bonnybridge are the best known. A second source is the Ayrshire bauxitic clay.
A.B.S.

Ganister in Scotland. C. F. DAVIDSON. *Times Trade & Eng.*, **42** [889] xli (1938).—Ganister in Scotland is interbedded with seams of fire clay in the Midland Valley, but sandstone and quartzite (suitable for silica brick) from other geological formations occur in numerous localities throughout Scotland.
A.B.S.

Magnesite of East Siberia. A. A. ORSOEV. *Ogneupory*, **5** [6] 402–403 (1937).—The characteristics of large magnesite deposits located near Lake Baikal, East Siberia, are discussed.
M.V.C.

Mineral orientation in some olivine rich rocks from Rum and Skye. F. C. PHILLIPS. *Geol. Mag.*, **75**, 130–35 (1938).—The vibration direction of the alpha ray of olivine is oriented perpendicular to the plane of the fissility, while the vibration direction of the gamma ray is not oriented.
W.D.F.

Mineral production in India in 1935. ANON. *Indian & Eastern Engr.*, **80** [1] 60 (1937).—A résumé is given.
A.P.S.

Mineral resources of Greece. K. SCHLITTERMANN. *Berg- & Hüttenmänn. Monatshefte Montan. Hochschule Leoben*, **86** [1–2] 16–20 (1938).—Although at present not fully exploited there exist considerable deposits of minerals containing Sb, Pb-Zn, Cr, Fe, Cu, Ni, Mn, S, and bauxite, chromite, barytes, emery, asbestos, and talc; lignite is also mined. Geographical distribution, chemical composition, and ore dressing methods are described, and statistics of production since 1926 are appended.
M.H.

Oil shale. C. F. DAVIDSON. *Times Trade & Eng.*, **42** [889] xli (1938).—The oil-shale strata in Scotland form the upper part of the Calciferous Sandstone Series in the lowest main division of the Scottish Carboniferous System. The seams vary from a few inches to 12 ft. in thickness, and about 30 different beds have been worked. These shales were first distilled for oil in 1861, but the present annual output is 1,400,000 tons of shale valued at £430,000. About 25,000 tons of ammonium sulfate are produced annually as a by-product, and the manufacture of brick

from the spent shale is rapidly becoming an accessory industry. A.B.S.

Physicochemical properties of colloidal clay solutions. A. Boutaric and S. Thevenet. *Ann. agron.*, **7**, 389–408 (1937); abstracted in *Chem. Zentr.*, **1938, i**, 280.—The clay investigated consisted of aluminum silicate and about 10% highly dispersed quartz. The following properties were studied: (1) viscosity as a function of concentration; (2) effect of acetone and alcohol on viscosity of clay solutions; (3) effect of electrolyte on viscosity; (4) irreversible conversion of colloidal clay solutions; (5) flaking; (6) optical properties; and (7) capillary rising in porous bodies. It was found that the majority of properties of colloidal clays correspond to those of hydrophobic colloids; with regard to viscosity, clay colloids have an intermediate place between hydrophilic and hydrophobic colloids. M.V.C.

Refractory clays from Ol'gino. I. P. Romankevich and V. E. Sliviko. *Ogneupory*, **5** [8] 563–67 (1937).—The study of ceramic properties of Ol'gino refractory clays showed that they possess an average refractoriness and plasticity, have a low shrinkage on firing, and sinter at over 1300°C. M.V.C.

Rock weathering. Samuel S. Goldich. *Jour. Geol.*, **46** [1] 17–58 (1938).—G. attempts to analyze the chemical and mineralogical changes produced in the weathering of a granite gneiss from Minnesota, diabases from Massachusetts and Minnesota, and an amphibolite from the Black Hills. There is a marked early loss of soda and lime and a more gradual loss of potash and baryta in the granite gneiss, with kaolinite as an end product. The Lake Superior diabase shows little chemical change except oxidation. The amphibolite yielded beidellite or related clay minerals by decomposition of hornblende. G. proposes a mineral-stability series in weathering. The arrangement of the common rock-forming minerals in this series is found to coincide with the reaction series. Experimental work on the attack of silicate minerals by water is in accord with the suggested mineral-stability series. Numerous tables of analyses are given. A.C.B.

Russian aluminum. Robert J. Anderson. *Mining Mag.*, **58**, 73–86 (1938).—One of the earlier known ore deposits was a laterite near Leningrad, but it was poor and rapidly running out. Recently on the eastern slope of the Urals one large high-grade body of bauxite and many smaller ones have been found. Later, rich deposits to the west of the Urals were located. The estimated reserves total 45 million tons. In the Kola peninsula, arctic Russia, there are deposits of apatite and nepheline (see "Apatite—," this issue, p. 229). The apatite is used for superphosphate, and a process has been developed to use the nepheline tailings for the production of alumina, soda ash, and potassium salts. Alunite, leucite, clay, and coal ash have been investigated as a source of alumina. Cryolite does not occur in the Soviet Union, and several plants are being constructed to make it synthetically. W.D.F.

"Single value" soil properties—study of the significance of certain soil constants: VIII, Relationships between the sticky point and the nature of the exchangeable ions in the soil. J. R. H. Coutts. *Jour. Agr. Sci.*, **25** [4] 523–28 (1935).—Earlier papers in this series have dealt with (1) considerations of technique of certain physical measurements, and (2) attempts to explain the significance of the results from the standpoint of generally accepted colloidal theories of soil behavior. In the present work, variations in the sticky point of homionic soils, as determined by kneading with electrolytic solutions, are investigated. For sodium soils a well-marked maximum has been observed on the sticky point/electrolytic concentration curve. The form of the curve exhibits parallelism with the extent of flocculation produced by varying electrolytic concentrations. For Parts **VI–VII** see *Ceram. Abs.*, **11** [7] 427–28 (1932). P.S.D.

Soil moisture meter. W. S. Rogers. *Jour. Agr. Sci.*, **25** [3] 326–43 (1935).—R. describes fully a moisture meter which gives direct and continuous measurements of the soil moisture content. The instrument consists essentially of a special porous container filled with water, connected by a tube to a mercury manometer. The container is buried in the soil, whose capillary pull causes the mercury to rise. The height of rise of mercury is dependent upon the amount of moisture in the soil, the size of the soil particles, and the degree of soil compactness. Applications of the instrument in the field and in the laboratory are given. Illustrated. P.S.D.

Spinel, corundum, and titano-magnetite deposit in the Khakassiya region (Minusinsk district) in Siberia. S. M. Kurbatov and L. L. Solodovnikova. *Trav. inst. Lomonossoff géochim., crist. minéral.*, **1935**, No. 5, pp. 113–21 (in German 122); *Chem. Abs.*, **32**, 1616 (1938).—Microscopic and chemical analyses are given. The deposit contains spinel up to 60, corundum 4.5 to 50, and titano-magnetite (allotriomorphic-granular aggregate of magnetite and ilmenite) not over 45% of the total aggregate. Five references.

Tropical soils: increase of acidity with depth. H. C. Doyne. *Jour. Agr. Sci.*, **25** [2] 192–97 (1935).—A number of tropical Nigerian soil profiles have been studied by determination of the p_H and the exchangeable bases at various depths up to 70 in. below the surface. The common, though not invariable, feature of many tropical soils, *viz.*, increase of acidity with depth, is noted. The soils investigated are divided into three groups: (1) acidity increase confined to the horizon immediately below the surface, subsequent horizons showing no regular increase or decrease; (2) acidity increase to a definite depth below which there is a regular decrease; and (3) acidity increase continuing without a break into the decomposing rock beneath. Examples and possible, though tentative, explanations are given for the above soil types. P.S.D.

Uniform classification of ceramic plastic earths. O. Kallauner. *Internat. Assn. Testing Materials, London Congr., April, 1937*, pp. 154–56; abstracted in *Referat. Silikatliteratur*, **4** [7] 4238 (1937). M.V.C.

Zinc oxide and zinc white in the glass and enamel industries. Zschacke. *Glashütte*, **68** [4] 50–51 (1938).—Z. describes methods used in the production of zinc oxide from slag and ores and zinc white from metallic zinc. See *Ceram. Abs.*, **17** [2] 67 (1938). M.V.C.

BOOKS

Atomic Structure of Minerals. W. L. Bragg. Cornell Univ. Press, Ithaca, 1937. xiii + 292 pp. Price $3.75

Reviewed in *Nature*, **140** [3549] 783–84 (1937); *Science News Letter*, **31** [845] 400 (1937).—B. gives a short introduction to space lattice crystallography and crystal analysis by X-rays. The major portion of the book is devoted to a description of actual mineral structures with special emphasis on the silicates. Illustrated.

J.L.G. + P.G.H.

Bauxites: Vol. I, Part II. Edited by A. D. ARKHANGELSKIĬ. *Trudy Vsesoyuz. Nauch.-Issledovatel. Inst. Mineral. Syr'ya*, **1936**, No. 3, 230 pp. Price 10R. Various authors describe bauxite deposits in Russia and their origin.

M.V.C.

Physics in Industry. KARL T. COMPTON, E. C. SULLIVAN, ZAY JEFFRIES, E. Q. ADAMS, PAUL D. FOOTE, J. P. DEN HARTOG, JOHN ELY BURCHARD, OLIVER E. BUCKLEY, CLARK B. MILLIKAN, JOSEPH SLEPIAN, HOMER L. DODGE, AND A. R. OLPIN. American Institute of Physics, New York, 1937. xiv + 290 pp. Price $1.50. Briefly reviewed in *Nature*, **141** [3562] 225 (1938).—A symposium is given of essays on physics in industry by different American authorities in the glass, metal, oil, and other industries. It is recommended as interesting and valuable to research workers, engineers, and laymen. J.L.G.

PATENT

Method of removing iron from naturally occurring magnesium silicates. STEATIT-MAGNESIA AKT.-GES. Brit. 482,243, April 6, 1938 (July 14, 1936).

Chemistry and Physics

Adsorption of proteides. Effects of salts on the adsorption of hemoglobin by kaolin. MLADEN PAIĆ AND V. DEUTSCH. *Compt. Rend.*, **202** [18] 1514–19 (1936).—Further curves were established for the adsorption as a function of the kaolin content of the solution; the p_H value of the latter decreases with increase in kaolin. Tellurates of potassium were investigated as salts; they behave similarly to sulfates and selenates. See *Ceram. Abs.*, **17** [3] 118 (1938). M.H.

Chemical studies of silicates: VI, Behavior of enstatite ($MgSiO_3$) toward fused chlorides of bivalent metals. ERICH THILO. *Ber. Deut. Chem. Ges.*, **70** [11] 2267–72 (1937).—In a former report, the behavior of talc toward fused chlorides of bivalent metals was described. The results indicate that talc reacts with metal chlorides ($MeCl_2$) according to the following equation: $Mg_3[Si_4O_{10}](OH)_2 + MeCl_2 \rightarrow 3MgSiO_3 + SiO_2 + MeO + 2HCl$, *i.e.*, magnesium metasilicate, free quartz, metal oxide, and hydrochloric acid. In a secondary reaction the change of a partly ortho-, partly meta-, silicate takes place. An exchange of the Mg from the Mg metasilicate against the cation of the chlorides takes place as follows: $MgSiO_3 + MeCl_2 \rightarrow MeSiO_3 + MgCl_2$; *e.g.*, $CoCl_2$ was used in amounts of 15% atomic weight. To determine whether this exchange reaction (well-known for zeolites) is solely confined to the $MgSiO_3$ obtained from the above dissociation of talc, similar tests were carried out on a natural $MgSiO_3$, enstatite. $CaCl_2$, $MnCl_2$, $CoCl_2$, $NiCl_2$, $ZnCl_2$, and $CdCl_2$ were used. With powdered enstatite heated to approximately 800°C (oxygen excluded) a definite exchange of cations, $Mg^{\cdot\cdot}$ (and $Fe^{\cdot\cdot}$), took place. The resulting products were examined by X-ray (Debye diagrams) and found to be mixed crystals with the structure of enstatite. Chemical analyses were also made of all compounds. **VII, Magnesium metasilicate formed in the thermal decomposition of talc.** *Ibid.*, [12] 2373–81.—In the thermal decomposition of talc, there is formed, besides water, a mixture of magnesium metasilicate and silica, $Mg_3[Si_4O_{10}](OH)_2 \rightarrow 3MgSiO_3 + SiO_2 + H_2O$. The free silica may easily be removed with a dilute solution of caustic soda. The residual metasilicate was thought by former investigators to be enstatite or clinoenstatite. H. Haraldsen has shown by X-ray, however, that this metasilicate, formed from talc at approximately 900°C (first amorphous, then crystalline at increased time-temperature), has not the structure of enstatite nor that of clinoenstatite. It is a new, hitherto unknown modification of $MgSiO_3$. H. also found that this same $MgSiO_3$ modification is found by heating MgO and SiO_2 to 1300° to 1400°C. The name of "Metatalc" has been proposed for this compound. X-ray studies (Debye exposures) were made of this modification to determine its relationship to the natural compounds, *i.e.*, enstatite and clinoenstatite. The thermal decomposition of a talc from Mautern (Austria) at various temperatures was investigated. T. reached the following conclusions: $MgSiO_3$ (Metatalc) as obtained from natural talc can also be obtained, by reactions in the solid state, by heating olivine and SiO_2 and from MgO plus SiO_2 heated also to 1250°C. In the presence of LiF as mineralizer, Metatalc is transformed at 790°C into enstatite. Amorphous SiO_2 is changed into quartz under the same conditions. A transformation of enstatite into Metatalc does not take place at 1250°C, even with additions of MgO, SiO_2, or Metatalc; the enstatite always changes into clinoenstatite. For Parts **IV–V** see *Ceram. Abs.*, **16** [10] 311 (1937). L.E.T.

Formation of zones in a silicate melt containing fluorine. D. P. GRIGOR'EV. *Zapiski Vserossiĭskogo Mineral. Obshchestva*, **66** [1] 118–23 (1937); abstracted in *Chem. Zentr.*, **1938**, **i**, 44.—A mixture of 50 SiO_2, 10 Al_2O_3, 20 CaF_2, 12.5 MgO, and 7.5% K_2O was melted at 1400° and slowly cooled. Several zones were found in the cooled melt. The upper zone, consisting of glass and pyroxene was followed by a zone of amphibole crystals, then amphibole and mica grains in a dark colored mass, and finally by mica in the ground mass. Solidification proceeds from the outside toward the inner part of the mass. A hard crust of pyroxene is first formed; amphibole crystals grow on this crust with a diffusion of amphibole molecules. The interior of the mass, which is still liquid, is enriched by mica components which later crystallize. In the transfer zone, amphibole crystallizes first and then reacts with the melt, forming mica with a lowering of the temperature.

M.V.C.

Fusibility of zinc-bearing slags of the system FeO–CaO–ZnO–SiO_2. M. V. ZAITSEV AND E. J. FEIGINA. *Tsvetnye Metal.*, **1936**, No. 4, pp. 60–75; *Metals & Alloys*, **8** [11] MA659 (1937).—FeO-SiO_2-CaO slags, of compositions occurring in smelting Cu and Pb sulfide concentrates, were prepared by melting materials in Fe and/or Al_2O_3 crucibles

with free access of air. Melts were also prepared containing 0.5 to 14.7% ZnO. Isothermal liquidus curves, determined by means of cooling curves, were plotted on the FeO-CaO-SiO_2 base for the following ranges of ZnO concentrations: 0 to 4, 4 to 8, and 8 to 14% ZnO. The isotherms indicate that the addition of 4 to 8% ZnO lowers the liquidus temperatures of the system, while further addition, 8 to 14% ZnO, raises the liquidus temperatures. The diagrams also indicate a shift in the liquidus isotherms resulting from the addition of ZnO. 19 references.

"Green" color of zircon. KARL CHUDOBA. *Deut. Goldschmiede-Ztg.*, **40**, 410–11 (1937); abstracted in *Chem. Zentr.*, **1938, i**, 45 (1938).—Zircon minerals of green, yellow-green, and brown colors have a low density. X-rays show that the difference in color is correlated with the structure of zircon. The green color indicates that the mineral underwent a marked disintegration of $ZrSiO_4$ into amorphous SiO_2 and amorphous and crystalline ZrO_2. Zircon of high density consists of crystalline $ZrSiO_4$. When heated to 1450°C, green zircons turn blue and yellow. See "Density—," *Ceram. Abs.*, **16** [8] 256 (1937). M.V.C.

Influence of impurities on reactions between iron melts, iron-manganese silicates, and solid silica. F. KÖRBER. *Jernkontorets Ann.*, **121**, 319–54 (1937); *Brit. Chem. Abs.–B*, **56**, 1347 (1937).—The influence of C, P, S, Co, Ni, Cu, CaO, Al_2O_3, and TiO_2 on the equilibria in the system Fe–Mn–Si–O has been studied, and technical consequences are discussed. An examination of impurities in the melt shows that C reduces SiO_2 to Si and also forms Fe and Mn carbides, both effects causing the equilibrium in the reaction $2Mn + SiO_2 \rightleftharpoons 2MnO + Si$ to lie over to the left. Thus high-C, high-Mn steels can be smelted without excessive loss of Mn in the slag. The importance of the Si isotherm is stressed, and examples of its technical application are given. P has a similar action to C, but in practice its concentration is too low to have any effect. While there is good evidence of the formation of Fe_3P, Mn phosphides can not be detected. The equilibrium in the reaction $Mn + FeS \rightleftharpoons MnS + Fe$ lies far over to the left in the metal phase, but in the presence of a slag layer it lies to the right, owing to the preferential solubility of MnS in the slag. Equilibrium is further disturbed by the reduction of SiO_2 by MnS, which is incomplete, leading to the dilution of the metallic oxides and a shift of the equilibrium $2Fe\ (Mn) + SiO_2 \rightleftharpoons 2Fe(Mn)O + Si$ to the right. The net effect is to leave unchanged the reactivity of Mn toward SiO_2. Other metals inhibit the reaction $2Mn + SiO_2 \rightarrow 2MnO + Si$ in the order Cu > Ni > Co. Impurities in the slag, such as CaO, Al_2O_3, and TiO_2, act as diluents of the FeO and MnO, and further reduction of SiO_2 takes place to restore equilibrium in the slag phase. Thus they cause great loss of Mn. There is very little reduction; with a slag containing 50% of TiO_2 and 50% of SiO_2, the melt contains 2% of Si and only 0.02% of Ti. Practical applications to the existing processes are discussed.

Lithium minerals and compounds in ceramics. GEORGE C. BETZ. *Jour. Amer. Ceram. Soc.*, **21** [5] 189–91 (1938).

Photographic and spectrographic study of the colors of slag constituents. HELGE LÖFQUIST. *Tek. Tid.* [Section Bergsvetenskap], **67**, 77–83 (Oct. 9, 1937); *Metals & Alloys*, **9** [2] MA105 (1938).—L. studied the possibilities of producing, by color filters or by spectrographic means, an improved color characterization of various common slag constituents. The reflective power of a material increases with its refractory and absorption index. The former is of importance for transparent materials; the latter is more important for opaque substances. Because of variations in the magnitude of these indices, it is possible to attain different color combinations both with reflected and with transmitted light. In microscopic studies of slag inclusions in Fe and steel, it is very important to obtain as great a difference as possible between the colors of the various inclusions. The simplest method is by a correct selection of color filters and by using the proper photographic plates. It is thus possible to make the inclusions stand out distinctly against the steel matrix so that the various constituents of the inclusions may be identified. For more exact classification of the colors, spectrographic methods are required. The direct spectrographic analysis of slag substances having similar appearances in reflected light such as (Fe, Mn)O, Mn silicate, Fe silicate, and Ca silicate gave no easily detected differences. It is not unlikely, however, that exact photometric examinations with a very sensitive spectroscope may reveal great differences. The variation in the total reflective power is quite distinct. This method of testing will probably be most effective for transparent slag constituents, using transmitted light, since the color variations are of greater magnitude for such substances.

Preservation of ammonium molybdate reagent. SHOICHIRO SAITO. *Science Repts. Tôhoku Imp. Univ., Series 1*, **26**, 252–60 (1937).—The standard solution contains 75 g./liter ammonium molybdate and is $3N$ in HNO_3. This soon forms a yellow crystalline precipitate and becomes worthless. This yellow precipitate is $MoO_3 \cdot 2H_2O$. To determine the solubility of this compound, various concentrations of nitric acid were made up and allowed to stand in contact with it for several months; the greatest amount was dissolved by the $5N$ HNO_3. Various concentrations of ammonium molybdate and nitric acid were also made up, and crystals of $MoO_3 \cdot 2H_2O$ were introduced into some of these. Without the nucleus, the reactions were slower but identical. Light had no effect. From this study the recommended reagent should contain 25 g./liter solid ammonium molybdate and be $5N$ in HNO_3. This is undersaturated with $MoO_3 \cdot 2H_2O$; the 75 g./liter solution was highly supersaturated, but because of its slow nucleus formation and slow crystal growth such a solution could be used for a short time. W.D.F.

Preservation of the standard solution of potassium permanganate. TAKIO KATO. *Science Repts. Tôhoku Imp. Univ., Series 1*, **26**, 297–302 (1937).—K. found that manganese dioxide and sunlight were most important in decomposing the solution. The recommended procedure is to dissolve the commercial permanganate in distilled water, boil 2 hr., let stand one day, filter through asbestos or glass wool, and keep in a steamed-out bottle covered with black paper. A 0.1 N solution prepared in this manner and left to stand for one year gained 0.00004 N. W.D.F.

Quantitative determination of selenium. ZEN-ICHI SHIBATA. *Science Repts. Tôhoku Imp. Univ., Series 1*, **26**

248–52 (1937).—Solutions of selenic acid in HNO_3 lose selenium when evaporated repeatedly with HCl to remove HNO_3. Connecting a reflux condenser to the flask prevented this. When free of HNO_3, the solution is diluted to 200 to 300 cc. with water saturated with SO_2 and boiled until the red selenium first precipitated changes to a gray easily filterable modification. This is filtered in a porous crucible, washed with water and alcohol, dried at 105°C, and weighed. A large volume of solution should be first neutralized and concentrated and then treated as above. In volumetric analysis an excess of KI is added. The liberated selenium obscures the end point of the iodine. An improvement is made by adding benzol and shaking, whereby the selenium is adsorbed at the interface. W.D.F.

Separation of Fe, Al, Cr, U, Zr, and Ti from Mn, Co, Ni, Ca, Sr, Ba, Mg, and alkaline metals by means of pyridine as reagent. E. A. Ostroumow. *Ann. Chim. Anal. Chim. Appl.*, **20** [1] 9–12 (1938).—Pyridine quantitatively separates Fe, Al, Cr, U, Zr, and Ti from Mn, Co, Ni, Ca, Sr, Ba, Mg, and alkaline metals in slightly acidic solutions. Great advantage is gained by making use of this reagent due to the rapidity of the procedure and to the purity of the precipitate characterized by a small adsorbing power. A single precipitation generally suffices. R.W.D.

Spectrographic analysis of certain materials to determine their conformity to specifications. Jacob Sherman and W. J. Jeffries. *Jour. Amer. Soc. Naval Engrs.*, **50** [1] 39–50 (1938).—Fundamentals are reviewed, and data obtained are discussed. The Navy's interest in spectrograph analysis is in shortening the time between inspection and acceptance of materials. Assurance of conformity of material to specification limits is obtained even when minor constituents which have a maximum "impurity" requirement are present. W.H.B.

System sodium metasilicate–water from 90°C to the ice point. C. L. Baker and L. R. Jue. *Jour. Phys. Chem.*, **42** [2] 165–69 (1938).—The phase equilibria for the system sodium metasilicate–water were determined between 90°C and the ice point. The latter was found by rotating in a Dewar flask until analyses on successive days showed that equilibrium had been established. C.J.P.

Ternary compound $Mg_4Cu_{11}Al_{11}$. W. Schütz. *Metallwirtschaft*, **16** [38] 949–50 (1937).—Experiments and theoretical considerations prove that the formula of the compound $Mg_3Cu_7Al_{10}$ is in fact $Mg_4Cu_{11}Al_{11}$. M.H.

Ternary and quaternary systems alkali oxide–CaO–SiO_2–CO_2. Equilibrium, reaction velocities, and their relation to glassmelting processes: I (*concluded*). C. Kröger. *Glastech. Ber.*, **15** [11] 403–16 (1937).—The system CaO–SiO_2–CO_2 is discussed. The mechanism of reactions is considered from the viewpoint of Tammann, and some thermochemical data on the formation of silicates are summarized. 69 additional references. See *Ceram. Abs.*, **17** [5] 202 (1938). J.F.H.

Theory of diffusion in solids. John E. Dorn and Oscar E. Harder. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 836, 19 pp. (1937); *Metals Tech.*, **4**, No. 6 (1937).—This paper is limited to diffusion within the crystal lattice. Each atom in a pure crystal lattice is held in position by identical forces but, owing to thermal effects, may oscillate about a mean position. Generally, it will merely oscillate back and forth, but if greater kinetic energy is obtained it may break loose from its bonds. The probability of loosening increases with rising temperature, but the time to break loose does not change. This is self diffusion. For diffusion within a lattice the different diffusing atoms must form solid solutions. One type is interstitial, where a small atom occupies the spaces between the larger atoms, as carbon in gamma iron. The most effective forces holding it come from its close neighbors, and diffusibility is found to increase with decreasing solubility. In substitutional solid solution in a perfect lattice with no holes, the foreign atom must interchange with one of the original atoms. The bonds to the foreign atom are different; if weaker, the solid solution melts at a lower temperature and the foreign atom diffuses faster. Equations for interstitial and substitutional diffusion are developed and applied to experimental results. W.D.F.

Theory of melting and of plastic deformation of solids. V. Zhdanov. *Verhandl. siberisch. physik.-tech. Inst. Kujbyschev Staats-Univ. Tomsk*, **4**, 163–76 (in English 177) (1936); *Chem. Abs.*, **32**, 1535 (1938).—It is assumed that in a solid body consisting of a system of oscillators, when the energy, E, of a given oscillator becomes greater than a certain critical value, E_m, which is a function of the frequency and mass of the oscillator and of the distance between it and adjacent oscillators, the oscillator changes from a stable to an unstable state and moves in one direction, thus changing the position of equilibrium. At the melting point of the solid the number of unstable oscillators calculated statistically is $\sim 1/1000$ of the total number. An expression for the melting point of solids is deduced from these considerations.

Thickness of oxide films on iron. H. A. Miley. *Iron & Coal Trades Rev.*, **134** [3613] 965–66; [3614] 1014–15 (1937).—M. discusses the different physical and chemical methods of determining the thickness of oxide films with regard to their accuracy and describes a new electrical method in which the number of coulombs of electric current necessary to reduce the film of ferric oxide to ferrous oxide is measured; the conversion formula of millicoulombs into thickness in Å per sq. cm. is $t = M \times 10^8/(2D \times 99{,}494 \times 10^4)$, where M is the weight of oxide furnishing one gram atom of O on cathodic reaction, D is the density of the oxide, and t is the thickness. The types of oxide formed at different temperatures are (1) γ-Fe_2O_3 from room temperature to 200°C; (2) α-Fe_2O_3 from 200° to 400°C; (3) α-Fe_2O_3 with an underlying layer of Fe_3O_4 from 400° to 575°C; and (4) α-Fe_2O_3, Fe_3O_4, and FeO (next to the metal) above 575°C. M.H.

Viscosity of blast-furnace slags. N. V. Rulla. *Teoriya & Prakt. Met.*, **9** [11] 20–37 (1937); *Chem. Abs.*, **32**, 1625 (1938).—The viscosity and temperature of primary crystallization of natural blast-furnace slags were determined. The slags used (over 200 samples) contained SiO_2 24.58 to 42.07 and Al_2O_3 4.37 to 28.23%; in most cases FeO did not exceed 1.76, MgO 5, MnO 5 to 6, and CaS 7%. Slags were classified as (I) CaS/(MgO + MnO) = 2 to 5, $SiO_2 + Al_2O_3 + CaO$ = 90 to 93%, MgO/MnO = 3 to 9; (II) CaS/(MgO + MnO) = 0.6 to 2, $SiO_2 + Al_2O_3 + CaO$ = 84 to 90%, MgO/MnO = 0.5 to 3; and (III) CaS/(MgO + MnO) = 0.7 to 1.8, $SiO_2 + Al_2O_3 +$

CaO = 88 to 92%, MgO/MnO > 3. In group I at 1400° the slags containing 15 to 25% Al_2O_3 and 40 to 35% SiO_2 lack fluidity. An increase to 1450° lowers the η of slags containing 5 to 12% Al_2O_3 and 40 to 45% SiO_2; this is not true of slags containing 40 to 45% SiO_2 but over 15% Al_2O_3. A rise to 1500° has no effect upon the η. An increase to 1550° reduces the η of basic slags more sharply than that of acidic slags having the same alumina content. The most fluid slags at a low temperature contain over 44% SiO_2 and 5 to 11% Al_2O_3. Slags most stable in regard to η contain about 45% SiO_2 and 8 to 9% Al_2O_3. In group II the most fluid slags contain 8 to 16% Al_2O_3 and 42 to 38% SiO_2. The region of minimum η corresponds to $SiO_2/CaO = 0.82$. When $SiO_2/CaO > 0.82$, the slags are more stable in regard to η and the temperature of primary crystallization. In group III the addition of 3 to 5% MgO considerably enlarges the extent of fluidity. Slags containing over 7% Al_2O_3 and 40% SiO_2 at a temperature of over 1500° may have a lower η than the slags in group II. For slags of all 3 groups located in the region of Al_2O_3 8 to 13, SiO_2 39 to 43, and CaO 45 to 49%, a change in any of these components has only a slight effect upon the η, especially over 1450°. Within the same region, the effects of MgO, MnO, and CaS upon the η were investigated in about 50 samples containing 2 to 12 MgO, 0.5 to 6 MnO, and 4 to 15% CaS. Σ(MgO + MnO + CaS) was limited to 11 to 18%. Diagrams of η for 1450°, 1500°, and 1550° were constructed. The η diagrams for the 3-component system SiO_2–Al_2O_3–CaO agree well with the melting point diagrams of Wright and Rankin but they deviated considerably from the McCaffery η diagrams. Some of McCaffery's data are in doubt and should be used only with great care.

X-ray studies of hydrosilicate of nickel. E. F. Alekseeva and M. N. Godlevskiĭ. *Zapiski Vserossiĭskogo Mineral. Obshchestva*, **66** [1] 51–106 (1937); abstracted in *Chem. Zentr.*, **1938**, i, 45.—Data on a series of nickel hydrosilicates studied by means of X-rays and their chemical and microscopic analyses are given. M.V.C.

BOOKS

Elasticity, Plasticity, and Structure of Matter. R. Houwink. University Press, Cambridge, England, 1937. 374 pp. Price $6.00. Twelve of the thirteen chapters deal with the internal structure of matter in relation to its elastic and plastic behavior. The plasticity of crystals and amorphous substances, glass, resins, asphalt, rubber, etc., is discussed. One chapter (40 pages of text and 14 diagrams) deals exclusively with clay, its internal structure, double layers, water films, and attractive and repulsive forces between clay particles as the cause of their mutual separation in a sol and paste, concluding with the problems of thixotropy and a comparison between scientific and conventional methods of expressing plasticity. The elastic and plastic properties of clay, strain and stress relations, influence of temperatures, and electrolytes are also discussed. Practically all progress made during the last ten years in the knowledge of the nature of the plastic properties of clay is recorded and discussed. L.E.Thiess

Hydroxides and Oxyhydrates (Hydroxyde und Oxyhydrate). R. Fricke and G. F. Hüttig. (Vol. 9 of Handbuch der allgemeinen Chemie, published by Paul Walden.) Akademische Verlagsgesellschaft m.b.H., 1937. xx + 641 pp. Price 60 gold marks. Reviewed in *Nature*, **141** [3557] 6 (1938).—The authors describe the preparation and properties of nearly all the oxides and their hydroxides, including those of the rare earths. The sols and gels obtainable from many of the oxides are considered as well as the colloid chemistry of the well-known sols of hydrated metallic oxides. X-ray analysis of oxides and hydrates, their aging in both solid and colloidal condition, vapor pressures, velocity of hydration, solubility in alkalis, and their thermochemical, magnetic, and dielectric constants are considered. J.L.G.

Physics for Technical Students: Mechanics and Heat. W. B. Anderson. McGraw-Hill Book Co., Inc., New York, 1937. 3d ed. ix + 378 pp. Briefly reviewed in *Nature*, **141** [3562] 224 (1938).—A. treats the theory interestingly and gives numerous applications to industry in the two fields covered. J.L.G.

Symposium on Radiography and X-Ray Diffraction Methods, 1936. American Society for Testing Materials. 350 pp. Price $4.00. Reviewed in *Science News Letter*, **31** [835] 240 (1937).—The application of X-rays in the industrial field is dealt with. Illustrated. P.G.H.

PATENTS

Amorphous precipitated silica and method of preparing. R. V. Heuser (American Cyanamid Co.). U. S. 2,114,-123, April 12, 1938 (Nov. 1, 1935).

Making calcium metaphosphate. H. A. Curtis. U. S. 2,113,574, April 12, 1938 (August 17, 1935).

Making dicalcium phosphate. W. H. MacIntire. U. S. 2,108,940, Feb. 22, 1938 (May 3, 1934). The process of making dicalcium orthophosphate of approximately 95% purity consists in adding to an approximately 85% phosphoric acid solution an amount of approximately pure limestone comminuted to pass a 100-mesh sieve in the approximate proportion of 294 part. of H_3PO_4 and 300 parts of $CaCO_3$, together with water amounting by weight to 25% to 50% of the limestone, and vigorously agitating the mixture to a granular condition.

Manufacture and production of synthetic spinels. I. G. Farbenind. A.-G. Brit. 481,857, March 30, 1938 (July 29, 1936).

Manufacture of zinc oxide, particularly of zinc-white pigments. Smelting Metallurgischeund Metallwerke Akt.-Ges. Brit. 481,971, April 6, 1938 (Sept. 28, 1935).

Preparation of pure titanium dioxide. W. W. Plechner and A. W. Hixson (National Lead Co.). U. S. 2,113,945, April 12, 1938 (Nov. 23, 1934); U. S. 2,113,946, April 12, 1938 (Nov. 6, 1936).

Processes involving the melting of boric acid, borax, or phosphates. I. G. Farbenind. A.-G. Brit. 482,303, April 6, 1938 (Sept. 27, 1935).

Production of titanium dioxide pigments. W. J. Tennant (Titan Co., Inc.). Brit. 481,892, March 30, 1938 (Sept. 18, 1936).

Purifying boric acid. F. F. Berg (E. R. Squibb & Sons). U. S. 2,113,248, April 5, 1938 (Nov. 27, 1937). The process of purifying commercial-grade boric acid comprises recrystallizing the boric acid from an aqueous solu-

tion thereof containing a small proportion of a strong inorganic acid.

Sodium dichromate. "MONTECATINI SOCIETÀ" GÉNÉRAL PER L'INDUSTRIA MINERARIA ED AGRICOLA. Fr. 817,010, Aug. 24, 1937; *Chem. Abs.*, **32**, 1877 (1938).—In the manufacture of $Na_2Cr_2O_7$ from Na_2CrO_4, the Na_2SO_4 obtained as a by-product is purified by dissolving it in water and treating the solution with a reducing agent, *e.g.*, SO_2, to reduce Cr compounds. The solution is then boiled and made alkaline with soda, and the precipitated $Cr(OH)_3$ is separated and worked up. The residual solution is concentrated *in vacuo* to recover relatively pure Na_2SO_4.

Titanium pigment composition. L. W. RYAN AND W. J. CAUWENBERG (National Lead Co.). Can. 372,483, March 15, 1938 (March 10, 1936). G.M.H.

General

Charles Fergus Binns. J. F. MCMAHON. *Bull. Amer. Ceram. Soc.*, **17** [4] 174–76 (1938).

Choosing and protecting a trade mark. H. D. NIMS. *Ind. Marketing*, **21** [12] 21–22, 66 (1936).—The choice of a trade mark depends upon the nature of the product, the method of its use, and the place where it is to be used. Other important factors are whether the product is to be used in America or exported and its adaptability to modern conditions created by the use of radio, telephone, automobile, etc. The trade mark must be one which has not already been put to use by others. Trade marks are destined to become of increased importance in the distribution of goods as well as from the legal aspect. H.E.S.

Combustion instruments and control at Hell Gate. P. W. KEPPLER. *Combustion*, **8** [10] 29–33 (1937).—Of the 26 steam-generating units installed at Hell Gate Station, New York, 21 are stoker fired and 5 pulverized-coal fired. Of the latter, the two largest units have combustion control and are completely equipped with indicating and recording instruments. The operating procedure employed with the several groups of units is described in detail and the maintenance and care of the instruments is discussed. H.E.S.

Dust-filtering efficiency of the human nose. F. J. TOURANGEAU AND PHILIP DRINKER. *Jour. Ind. Hyg. & Toxicol.*, **19** [1] 53–57 (1937).—The nasal resistance to unidirectional air flows of 4, 8, and 12 liters per min. was determined upon normal subjects. The nasal filtering efficiency of the same subjects was then determined at the same rates of air flow. The determinations were made at air flows corresponding to nasal inhalation and exhalation. The dust used was finely divided limestone from which the large particles had been allowed to settle out. In general, nasal efficiencies were found to be less than 30%, indicating that the filtering efficiency of the normal nose is too low to be of importance in preventing fine dust from reaching the lungs. E.J.V.

Dust hazards and their control in a ceramic industry. T. C. ANGUS AND DONALD STEWART. *Jour. Ind. Hyg. & Toxicol.*, **19** [1] 58–71 (1937).—An investigation into the control of certain dust hazards in a ceramic industry has been carried out by the combination of clinical medicine, physical measurement, and engineering practice. Clinical and radiological evidence has shown that in the lungs of certain employees there is present some variation from the normal, suggestive of pneumoconiosis, the significance of which is at present impossible to assess. Further work is being carried out in relation to this finding. By means of dust counts, the zones in the factory associated with abnormal dust concentrations were determined. Specially constructed exhaust hoods at such danger zones have reduced the concentration of dust to limits believed to be safe. This has been the most important factor in removing the hazard, making these processes safe for operatives. The comparison of light-field and dark-field counts and the details of microscopy are appended. E.J.V.

Factors influencing design of pulverized coal-fired steam-generating units. O. DE LORENZI. *Combustion*, **8** [8] 33–35 (1937).—The design of a pulverized coal-fired steam-generating unit is influenced by many factors, among the more important of which are the extent and character of the load, the quality and characteristics of the coal, available space, and steam conditions. L. discusses the selection of the type of furnace, its proportioning, and the form of firing, with reference to load and fuel, as well as the disposition of heat-absorbing surface and the regulation of superheat. H.E.S.

Heat losses in boiler furnaces. P. JARRIER. *Chaleur & Ind.*, No. 214, pp. 207–16 (1938).—J. discusses items of heat balance and separately analyzes the heat losses due to the solid residue from combustion, the gaseous residue, and radiation and convection. Where the CO_2 content of the flue gases drops below 10%, loss of efficiency results by reason of the great volume of excess air which carries away sensible heat. The CO_2 content rarely increases above 13% without the presence of unburned gases and losses much greater than the saving by the lowered sensible heat of the air of combustion. The effect of furnace construction, fuel, and firing methods on each item of heat loss is given. A recording CO_2 meter would be of great value in increasing furnace efficiency. Tables are given. V.D.F.

How engineers may profit from patented inventions. L. T. PARKER. *Combustion*, **8** [9] 37–38 (1937).—In the recent case of Standard Parts *v.* Peck (264 U. S. 53) the U. S. Supreme Court rendered the decision that an engineer who perfects an invention in the employer's plant and while being paid by his employer has no legal interest in the patent. In order to secure exclusive ownership of patents obtained by engineers, the employer must include in the contract of employment a clause by which the employee agrees to assign all patents obtained while in the employment. The seller of a patented device can not restrict the uses to which the purchaser of the article may put it. If the prospective user refuses to contract according to the terms of the patentee, he can not in any manner gain an opportunity to use the patented equipment until the seventeenth year term of the patent expires. The higher courts hold consistently that when a patented machine wears out, the user must discard it. He can not make it over by sup-

plying new parts and repairs. This does not apply to broken parts but only to worn out parts. A license agreement is valid which, for instance, limits the use to which the user may put the patented device or equipment or by the terms of which a patentee grants privileges for a limited period. See *Ceram. Abs.*, **15** [4] 135–36 (1936). H.E.S.

Methods of sampling and dust determination in the mines of Ontario. GEORGE H. C. NORMAN. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 857, 20 pp.; *Mining Tech.*, **1**, No. 6 (1937).—The Devers konimeter is in regular use, taking a 5 cc. air sample by impinging it on a glass disk. A Zeiss microscope with a 15× eyepiece and a 10× objective is used for counting by dark-field illumination. This may show particles as small as 0.25 micron. The konimeter is 50 to 94% efficient. N. discusses the advantages and disadvantages of the konimeter, impinger, thermal precipitator, Owens jet dust counter, filter sampler, and photometric estimation of konimeter samples. Konimeter disks should be cleaned with pure filtered alcohol or chloroform and polished with cheesecloth; the konimeter should be checked once a year. The best adhesive for the disk is Nujol mineral oil. After taking the samples, the disks are ignited to cherry red, cooled, washed in 1:1 HCl for 2 min., washed in water and alcohol, and reignited. The konimeter sampling routine is taken up in detail, including preparation, sampling, heat treatment, acid treatment, and counting. The aim is to reduce dust counts below 300/cc. by ventilation, improved machinery, etc. Efficient respirators must be worn in higher dust concentrations. W.D.F.

Norton's house publications. NORTON COMPANY. *Ind. Marketing*, **21** [10] 36, 40 (1936).—Norton's experience with house organs dates back more than a quarter of a century, and its magazines, now published in several foreign languages, reach industrial plants throughout the world. *Grits & Grinds* deals with technical data on the uses of grinding wheels and grinding machinery, *Norton Floors* reaches the architects to promote nonslip floorings, *Handling Heat* features Norton refractories, and *Aëration & Filtration* goes to users of porous mediums. H.E.S.

Occurrence of silicosis in the manufacture of silicon alloys. TORSTEN BRUCE. *Jour. Ind. Hyg. & Toxicol.*, **19** [4] 155–62 (1937).—B. discusses the fact that silicosis attended by disability arises among workmen employed in the manufacture of silicon alloys. The dust found on the working premises is derived from the smoke which leaves the electric furnaces. The samples of dust taken close to the silicon furnaces consist, for the most part, of a finely divided powder of silica. Chemical analysis shows 89% SiO_2. In two factories for the production of silicon alloys where the workmen have been examined, silicosis develops at essentially different rates of speed. In one it takes 4 years for an early silicosis to develop, and cases of serious silicosis have occurred, attended by complete incapacity; in the other, 14 years are required, and no case of silicosis of a serious character has yet been found. The cause of this difference in the speed of development of silicosis is the difference in the measures taken for the technical prophylactic protection of the workmen. At the first plant the exhaust arrangements for the silica smoke are defective, the other factory has adopted comprehensive measures to prevent the dispersion of smoke from the silica furnaces into the working premises. E.J.V.

Petrographic method of dust analysis. CHARLES R. WILLIAMS. *Jour. Ind. Hyg. & Toxicol.*, **19** [1] 44–52 (1937).—General petrographic methods and their specific application to industrial dust analyses are presented. W. describes the equipment necessary, the physical and optical properties of minerals, with particular emphasis on those properties that are used in the identification of particles less than 10 microns in diameter, and the technique used. Limitations of the method are discussed. W. believes that the distribution of minerals by particle count in the respirable sizes is the important factor in industrial dust analysis. The petrographic method is the only way to determine this factor. Mineralogical composition may vary widely in different size ranges in the same sample. The quartz content of the whole sample may be quite different from the quartz content of the portion below 10 microns in size. This method has been applied to foundry dust, dusts from all types of quarrying and mining operations, glass-batch house dusts, talcs, asbestos, gypsum, clays, tile and brick dusts, parting compounds, etc., as well as numerous organic dusts. E.J.V.

Possible use of powdered glass in the ceramic industry. F. KNAPP. *Keram. Rundschau*, **45** [12] 134 (1937).—The sintering properties of powdered (waste) glass make advisable the use of electric heating in kilns of good design. F.E.V.

Prevention of accidents and occupational diseases. HARTMANN. *Ber. Deut. Keram. Ges.*, **17** [6] 315–22 (1936).—H. discusses the subject from the standpoint of prevention, cure, and compensation. The most common causes of accidents in pottery works are listed, and methods of preventing them are suggested. Following a discussion of silicosis, the necessary precautions to give dust-free working conditions are outlined. E.J.V.

Quartz in industrial dusts and deposits on human lung tissues: X-ray diffraction, chemical, and spectrographic studies. VICTOR HICKS, OLIVE MCELROY, AND MARY E. WARGA. *Jour. Ind. Hyg. & Toxicol.*, **19** [4] 177–86 (1937).—In studies of pneumoconiosis, it is desirable to have information concerning not only the elements present in dusts and deposits in lungs but also the state of chemical combination of these elements. Such information may be obtained qualitatively by a combination of spectrographic and X-ray diffraction analyses. The use of these methods is illustrated in the qualitative determination of silicon and quartz in industrial and air-borne dusts and deposits on human lungs. Both types of analyses may be made directly on the dusts. While spectrographic analyses may be made with either dry lung tissues or their ashes if proper precautions are observed, X-ray diffraction analyses of such preparations are uncertain and unsatisfactory. A method of separation of the deposit from the tissue by trypsin digestion is described. X-ray diffraction analyses of a number of lungs showed that small amounts of quartz may be present even when a lung is diagnosed pathologically as nonsilicotic. Quantitative chemical determinations of the silicon content of these lungs were made. Quartz is detected in the X-ray analysis of a lung tissue, the silicon content of which, as determined by the quan-

titative chemical analysis, was as low as 1.42 mg. of SiO_2/g. of dried tissue. E.J.V.

Relation of research to chemical plant construction. H. S. JACOBY. *Trans. Amer. Inst. Chem. Engrs.*, **32**, 87–99 (1936).—J. presents examples of improvement in building construction brought about by research. With more tolerance on the part of building ordinances and more effort on the part of the manufacturers, the chemical industry will be housed in a structure that is strong but light, with reasonable first cost and minimum maintenance expense. H.E.S.

Research work for the clay industry. G. R. RIGBY AND F. H. CLEWS. *Brit. Clayworker*, **46** [548] 292–94 (1937).—The Mellor Laboratories, headquarters of the British Refractories Research Association, are described. R.A.H.

Separation of substances by flotation. F. K. T. VAN ITERSON. *Proc. Koninkl. Akad. Wetenschappen Amsterdam*, **40** [2] 94–100; [3] 228–36 (1937); *Metals & Alloys*, **8** [11] MA658 (1937).—Flotation is reviewed under the following headings: geometry of flotation, some physical facts about surface tension, the action of flotation agents, collectors, frothing agents, activators, depressing agents, sulfidizers, promoters, conserving agents, p_H regulators, dispersing agents, the coal-slurry flotation plant of the State Mines in Limburg, and economical aspects of flotation.

Silica and silicate solubilities. ALBERT C. TITUS. *Jour. Ind. Hyg. & Toxicol.*, **19** [3] 138–45 (1937).—The blood serum and water solubilities, expressed as SiO_2, of finely powdered quartz, sericite, and a dolomitic chert were studied for two months at body temperature. Suspensions of the first two contained about 10 mg. and a suspension of the dolomitic chert about 100 mg./100 cc. About 0.05 mg. as SiO_2 of each dust was found to be in solution per 100 cc. of water. The solubilities in serum did not exceed the normal SiO_2 content of approximately 1 mg./100 cc. E.J.V.

Solubility of quartz in hydrofluoboric acid. WILLIAM B. HARRIS. *Jour. Ind. Hyg. & Toxicol.*, **19** [8] 463–64 (1937).—Checking the results of other workers with respect to solubility of quartz in the presence of other silicates, it was found that quartz particles below 5μ are approximately as soluble in hydrofluoboric acid as in hydrofluosilicic acid. E.J.V.

Specific enthalpy of low-pressure steam. C. H. BERRY. *Combustion*, **8** [10] 41–42 (1937).—B. gives three simple equations for computing enthalpy which are applicable to three temperature ranges and which, for temperatures above 100°F, are in agreement with the latest steam tables within 2%, a degree of accuracy acceptable for many purposes. A chart is plotted showing the differences. H.E.S.

Windsor steam plant modernization. P. SPORN. *Combustion*, **8** [9] 20–24 (1937).—The topping being installed at the Windsor Station consists of two 750,000-lb./hr. units supplying steam at 1250 lb. and 925°F total temperature to a 60,000-kw. 3600-r.p.m. turbine generator exhausting to three existing low-pressure turbine generators of 90,000-kw. combined capacity. One of the steam-generating units will have a slagging type of furnace and the other, a dry-bottom type. Each employs different and novel means of superheat control. H.E.S.

BOOKS AND BULLETINS

Market for Columbia River Hydroelectric Power Using Northwest Minerals. EDWIN T. HODGE. War Department, Office of the Division Engineer, North Pacific Division, Portland, Oregon, January, 1938. Mimeographed. 4 vols. 1079 pp., 177 plates and tables. Price $12.50. H. presents an extensive geological and technological report on Northwest clays and other clays available for Northwest use. **Vol. I, Magnesia.** The possible electric power applications, types and classifications of clays, economics of clay mining and purification, the uses of quartz and mica as by-products, kaolin costs at Pacific Coast ports, and the sampling and testing of clays are discussed. **Vol. II, Silica.** The following subjects are dealt with: clay technology for the production of aluminum, alumina, and aluminum salts; refractories made of fused alumina, mullite, and fire clay; pottery and other ceramic products; industrial fillers, ultramarine manufacture, and other minor uses; electric firing of ceramic products and mechanical pottery manufacture and costs; electric furnace products and practice; and the estimated future demands for clay in the West. A list of western pulp and paper mills is included. **Vol. III, Limestone.** H. treats of the clays of Washington and Idaho. The geology of the various clay regions and a detailed description of the principal mines, pits, and plants are given. Refractories manufacture is emphasized. A geological review of a reported alunite-bearing area in western Wash. is added. **Vol. IV, Northwest Clays.** Clays of western Oregon, California, Nevada, eastern United States, Europe, and some trans-Pacific areas, which might be used on the Pacific Coast for special purposes, are described. A summary of all the deposits mentioned in the report is given together with the history and statistics of clay, a list of research activities relating to clay and clay products, and a bibliography.

Microprojection method for counting impinger dust samples. CARLTON E. BROWN, LESTER A. H. BAUM, WILLIAM P. YANT, AND HELMUTH H. SCHRENK. *U. S. Bur. Mines Repts. Investigations*, No. 3373, 9 pp. Free.—A method is described for counting impinger dust samples with a microprojector, eliminating eyestrain. See *Ceram. Abs.*, **15** [3] 101 (1936). R.A.H.

National Silicosis Conference: Summary Reports Submitted to the Secretary of Labor by Conference Committees, February 3, 1937. *U. S. Dept. Labor, Div. Labor Standards, Bull.*, No. 13, 56 pp. (1937). Supt. of Documents, Govt. Printing Office, Washington, D. C. Price 10¢.—Reports of the following committees are summarized: (1) medical, (2) engineering, (3) economic, legal, and insurance, and (4) regulatory and administrative. A list of references is included.

Petrographic identification of atmospheric dust particles. WILDER D. FOSTER AND H. H. SCHRENK. *U. S. Bur. Mines Repts. Investigations*, No. 3368, 10 pp. Free.—The authors describe a method of determining the composition of air-borne dust, a procedure frequently desirable in estimating hazardous qualities of a dusty atmosphere. R.A.H.

OFFICIAL PERSONNEL OF DIVISIONS, 1938–1939

	Art	Enamel	Glass	Materials and Equipment	Refractories	Structural Clay Products	Terra Cotta	White Wares
Trustee	L. E. Barringer	H. G. Wolfram	D. E. Sharp	G. H. Brown	C. E. Bales	J. L. Child	J. L. Carruthers	E. H. Fritz
Chairman	A. E. Baggs	G. H. Spencer-Strong	L. C. Roche	R. B. Carothers	N. W. Taylor	T. W. Garve	H. E. Davis	F. P. Hall
Vice-Chairman			N. W. Taylor	William Malkin	S. F. Walton	E. C. Clemens		
2nd Vice-Chairman			W. R. Lester					
Secretary	C. C. Engle	D. G. Bennett	S. R. Scholes	B. T. Bonnot	J. B. Austin	H. Z. Schofield		K. Schwartzwalder
Nominations	G. H. Stapleford W. A. Weldon	B. T. Sweely H. D. Carter G. H. McIntyre	G. W. Morey James Bailey	J. E. Eagle Tom Falknor	R. E. Birch H. M. Kraner	L. R. Whitaker G. R. Duncombe, Jr.	H. D. Callahan R. L. Clare	J. W. Hepplewhite R. E. Hanna
Editorial	R. G. Cowan E. de F. Curtis H. S. Nash	W. N. Harrison J. J. Canfield H. D. Carter	G. E. F. Lundell B. E. Warren James Bailey	R. R. Robinson G. W. Jarman M. C. Shaw	J. O. Everhart J. D. Sullivan C. M. Dodd	Ellis Lovejoy Howells Fréchette C. R. Austin		L. H. Brown H. F. Royal T. A. Klinefelter
Papers and Program	L. E. Barringer F. H. Rhead H. L. Bacher	W. H. Pfeiffer	N. W. Taylor W. R. Lester	W. H. Emerson B. M. Burchfiel S. S. Cole F. E. Finch	Gilbert Soler	E. W. Knapp	H. E. Davis D. F. Albery	Harry Thiemecke Ralston Russell W. W. Meyer
Membership	P. E. Cox C. C. Engle	W. V. Knowles	J. T. Ogden	C. H. Peddrick, Jr. J. E. Wiss E. L. Maxson L. N. Gill	R. S. Bradley	H. L. Longenecker		Donald Hagar
Standards	K. E. Smith	C. R. Amberg	G. W. Morey	F. S. Bell	S. M. Swain E. H. Van Schoick	H. L. Longenecker		R. M. Campbell
Research	F. H. Norton	W. N. Harrison	E. W. Tillotson	R. C. Meeker O. C. Ralston	G. R. Pole	H. R. Straight		S. J. McDowell
Education	M. L. Fosdick Glen Lukens		V. C. Swicker	A. A. Wells	H. E. White	J. L. Carruthers	E. E. Marbaker	F. H. Norton
Data	T. E. Ryder	J. E. Rosenberg		F. A. Guignon		H. G. Schurecht	E. E. Marbaker	Edward Schramm
Rules	C. M. Harder	R. D. Landrum	A. N. Finn	J. E. Eagle H. B. DuBois	K. E. Buck	G. H. Duncombe, Jr.		R. F. Sherwood
Councillors	Frederick Carder	F. R. Porter B. J. Sweo	F. C. Flint					R. F. Geller
Exhibitions	R. G. Cowan		R. M. Curts					L. E. Thiess
Industrial Management	Theodore Lenchner							F. H. Riddle